THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. I.

No. VI.—JUNE, 1914

ORIGINAL ARTICLES.

THE COMPLETION OF FIFTY YEARS OF THE *GEOLOGICAL MAGAZINE*.

THE publication of the 600th Number of the GEOLOGICAL MAGAZINE completes fifty years of its existence, and the Editor gladly avails himself of the occasion to express to his numerous friends and colleagues his most cordial thanks for their unfailing and generous support since 1864. Without their aid he would have been on many occasions at a loss to sustain the difficult task of providing for the monthly issue of the Magazine through so many years.

It is very gratifying to the Editor that the Rev. Osmond Fisher, M.A., F.G.S., Sir Archibald Geikie, K.C.B., P.P.R.S., F.G.S., Professor W. Boyd Dawkins, M.A., D.Sc., F.R.S., and Professor Edward Hull, M.A., LL.D., F.R.S., F.G.S. (who represent the contributors to the 1864 volume) have sent him letters of congratulation on his Jubilee; for, alas! by far the larger number of the early friends and supporters of the GEOLOGICAL MAGAZINE have "joined the majority". The ranks of the geologists have, nevertheless, maintained their strength, as will be seen by a reference to the retrospect of the work in the forty years from 1864 to 1903, in which a splendid record is furnished of geological and palæontological contributions, summarized by the late Horace B. Woodward and the Editor.[1] The subsequent decade (1904–14) has been no less prolific in good work. Indeed, one may venture to maintain that the quality of the contributions in these later years has been distinctly in advance of those preceding them; whilst the illustrations have increased very greatly both in numbers and excellence. Our friends the subscribers, too, have helped the Magazine with their kindly and necessary support, and if they will only continue, like our contributors, to increase in numbers its future happiness and success will be assured.

Letter from the Rev. Osmond Fisher, M.A., F.G.S., Hon. Fellow and late Tutor of Jesus College, Cambridge (æt. 97).

DEAR DR. WOODWARD,—I well remember meeting you at the rooms of the Geological Society, then at Somerset House, when you told me that you proposed to bring out a periodical in the science, and you asked me to contribute papers to it; I took this as a great compliment, and I think I may feel proud that none of my contributions to the GEOLOGICAL MAGAZINE have ever been refused admission.[2] You are

[1] See GEOL. MAG., January to April, 1904.

[2] Mr. Fisher's contributions to the GEOLOGICAL MAGAZINE number 109. His life and portrait appeared in the February number for 1900, p. 49.

to be congratulated that your scheme has been eminently successful, having now obtained the fiftieth year of honourable fulfilment. I look upon the "forty years' index" which you and Mrs. Woodward brought out in July, 1905, as a marvel of correctness and arrangement, making the series of volumes it covers—which I have had bound—serviceable for reference. May you long have health and strength to continue the editorship. Believe me, yours sincerely,

OSMOND FISHER.

GRAVELEY, HUNTINGDON.
May 11, 1914.

From Sir Archibald Geikie, O.M., K.C.B., P.Pres.R.S., D.C.L., LL.D., F.G.S., etc.

There can surely be but one opinion among geologists all over the world, that their favourite science lies under no small obligation for the constant support which, during half a century, it has received from the GEOLOGICAL MAGAZINE. At the start of this journal there were some critics who predicted that it would soon become extinct, for the portion of the public specially interested in geological science was believed to be too limited to sustain its circulation, even were the progress of observation and discovery ample enough to furnish a supply of material for its pages. How completely this pessimistic foreboding has been falsified, the issue of the 600th number of the Magazine abundantly testifies.

That there have been times of difficulty in the path of the Editor, and how successfully he emerged from them, is known to many of his well-wishers. To his energy, industry, and tact, his own personal scientific standing, his friendly relations with the workers in every branch of geological science, and his readiness to open his pages to every serious contribution which these workers might send him, the GEOLOGICAL MAGAZINE owes the unbroken continuity of its monthly appearance and the high character which it has maintained as a scientific periodical.

Dr. Henry Woodward well deserves unstinted congratulations and thanks from all students of geology. The service which his journal has rendered to the progress of every department of the science is difficult to estimate, but no serious reader of its pages can doubt that this service has been real and has been continuous from the very first. As one of the contributors to the first number of the Magazine and one who has been familiar with its contents ever since,[1] I am glad of this opportunity to record my own sense of the great usefulness of the journal, and my admiration of the skill and success with which he has guided its career through fifty eventful years.

ARCHIBALD GEIKIE.

ATHENÆUM CLUB.
May 11, 1914.

[1] Sir A. Geikie has made nearly fifty contributions to its pages, and his life appeared in the GEOL. MAG. for 1890, p. 49, and a portrait on the centenary of the Geological Society, see GEOL. MAG., January, 1907, p. 1, Pl. I.

From Professor W. Boyd Dawkins, M.A., D.Sc. (Oxon.), D.Sc. (Manch.), F.R.S., F.S.A., F.G.S., etc., etc.

My dear Woodward,—I write to congratulate you on the fiftieth anniversary of the Geological Magazine, and on your unique experience as founder and editor from the very beginning. I do not know another case in the history of science of so long and so successful a tenure of a like position.

As one of the four contributors to its first number now alive, and the writer of many articles in the Magazine during the past fifty years,[1] I wish to convey to you my sense of personal obligation for innumerable kind acts and wise counsels in my relation to you as Editor. The Magazine itself has had an important share in the spreading of geological knowledge. Its leading features have been fearlessness and independence, and absolute freedom from subservience to popular opinion, or to the influence of cliques or bureaux. It has maintained always a high level of excellence, and been supported by the leaders of geological thought of their day.

In the future, when you hand over the Editor's chair to your successor, you will have the joy of knowing that the Magazine will be carried on, as before, on your lines, through the eminent men who form the Committee,[2] and that your work will live. With all good wishes, I am, my dear Woodward, yours truly,

W. Boyd Dawkins.

The Athenæum Club, Pall Mall.
May 13, 1914.

From Professor Edward Hull, M.A., LL.D., F.R.S., F.G.S.

Dear Dr. Woodward,— . . . The work of Editor of the Geological Magazine for fifty years has reflected the greatest credit on your ability and extreme care of detail and accuracy in that rather delicate capacity, and I consider it is owing largely to these qualities that the Magazine has survived to the present day. I am surprised at what you say as regards the number of my own contributions,[3] and I certainly owe a debt of gratitude to the Geological Magazine, as, on more than one occasion, it has afforded a refuge for papers of my own intended for publication elsewhere.—Ever very truly yours,

Edward Hull.

14 Stanley Gardens, W.
May 11, 1914.

[1] Professor Boyd Dawkins has contributed forty articles to the Geological Magazine. His life and portrait appeared in the Geol. Mag., December, 1909, p. 529, Pl. XXX.

[2] The writer refers to the Editor's supporters whose names appear on the cover and on the title-page, namely: Professor J. W. Gregory, D.Sc., F.R.S., F.G.S.; Dr. George J. Hinde, F.R.S., F.G.S.; Sir Thomas Holland, K.C.I.E., A.R.C.S., D.Sc., F.R.S., F.G.S.; Dr. John Edward Marr, M.A., Sc.D. (Camb.), F.R.S., F.G.S.; Dr. J. J. H. Teall, M.A., Sc.D. (Camb.), LL.D., F.R.S., F.G.S.; Professor W. W. Watts, Sc.D., M.Sc., F.R.S., V.P.G.S.; Dr. Arthur Smith Woodward, F.R.S., F.L.S., Pres. Geol. Soc.

[3] Professor Hull has made 119 communications to the Geological Magazine between 1864 and 1914.

It may interest our readers to learn the record of the early efforts to provide an independent periodical publication for geologists in London.

1. In 1842 Mr. Charles Moxon published the *Geologist*, 8vo, two volumes (commencing January 1, 1842, ending in 1843). "A monthly record of Investigations and Discoveries in Geology, Mineralogy, and their Associate Sciences."

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3. In 1858 Mr. S. J. Mackie commenced to publish the *Geologist*, a monthly journal of geology, which extended to June, 1864, seven volumes, when it was purchased by Longmans and incorporated in the title of the Geological Magazine.

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Henry Woodward.

I.—On some Inclusions in the Great Whin Sill of Northumberland.

By John Armstrong Smythe, Ph.D., D.Sc.

(PLATE XVII.)

THE inclusions to be described in this paper occur in the Whin Sill at Snook Point on the coast of Northumberland. This is the most northerly exposure of the whin in the coast-section which stretches from Cullernose Point, through Dunstanburgh, to Beadnell Sands; and it is here that the outcrop leaves the coast and sweeps out to sea, to reappear further north in the Farne Islands and, on the mainland, at Bamburgh.

The exposure at Snook Point is a thin sill, one of two into which the whin seems to be split in this neighbourhood. It occupies the foreshore in the form of a triangular patch, about 70 yards broad at the shore-end, from the apex of which a spur is sent out to sea, in an easterly direction, for several hundred yards. The dip is south at a gentle angle, and the whin rests on sandstone and is overlain by limestone (the Great), both contacts being metamorphosed. The

[1] See Obituary, Geol. Mag., March, 1914, p. 142, with a Portrait.

thickness of the sill is only about 25 feet; the lower 15 feet is massive, with a tendency to columnar structure, the rock free from amygdules, coarse and breakable with equal ease in all directions. Above this the rock is bedded, amygdaloidal, finer in grain, and weathers in lumpy form. The topmost bed, however, in contact with the limestone, is free from amygdules, very fine in grain, vertically jointed, weathers into sharp, jagged points, and splinters under the hammer.

Near the middle of the triangular patch, high up among the bedded whin and just by the pool which is left at low tide, the rock takes on a dyke-like aspect, is well jointed in directions east and west and north and south, and breaks most readily along vertical planes. The apparent dyke is about 6 feet wide and it runs east and west, that is, parallel to the strike of the whin. In one place it forms an outstanding feature several feet high, but it cannot be traced far, as it seems to merge into the surrounding sheet.

The inclusions were first discovered in this dyke-like rock. The whole exposure of whin yielded, on systematic examination, about two hundred specimens, and the range of these was found to be restricted to the dyke-like mass and the bed of trap with which it appears to coalesce. The maximum dimensions of the rock with inclusions are about 90 by 20 feet, and by far the greater number of inclusions were found near the longer axis of this tract, which coincides with the 'dyke' and its prolongation.

The size of the inclusions varies from $\frac{1}{8}$ to $\frac{7}{8}$ in., but is usually about $\frac{3}{8}$ in., the same as that of the ordinary amygdules. They are characterized by a large number of facets, coated with a thin film of a mineral having a bronze-yellow or, occasionally, a reddish colour. When this film is chipped off a bright, reflecting plane surface is revealed, and similar surfaces line the whin in which the inclusions are embedded, the relations being similar to that of a mould and its cast. These surfaces and films constitute planes of weakness, and thus it happens that on breaking the rock a many-faced cast or knob and its mould are simultaneously disclosed; and, as the film clings most tenaciously to the knob, this generally has a bronze colour, while the mould is white and glassy. Occasionally the reverse is the case, the film lining the mould; and, again, patches of the film may be retained by both knob and mould, the bronze areas on the one corresponding to the white highly reflecting areas on the other.

It happens comparatively rarely that a knob is broken across; in such cases the inside usually appears to the naked eye to consist of ordinary whin; but at times, especially in weathered specimens, a difference is discernible, the rock being darker, finer-grained, and more easily scratched with a knife. When finely ground the powder from the inclusions has a dark-grey colour, that of the whin being somewhat brownish. On rare occasions weathered specimens show a general spherical form, and it may be remarked, in anticipation, that a corresponding circular outline is exhibited by the thin sections. Only one hemisphere, however, shows the multitudinous reflecting surfaces which are so characteristic of these inclusions. A completely facetted inclusion has never been secured, either by accident or design,

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and this observation has been confirmed by the experience gained in grinding the thin sections. In the fresh rocks there is no plane of weakness between the unfacetted portion of an inclusion and the surrounding normal whin, so that the spherical shape of the former is not displayed.

Another curious observation is deserving of mention. When the field-work was about half completed the general impression had been gained that the moulds of the inclusions, exposed by the breaking of the whin, faced upwards. Special attention was afterwards paid to this point and the impression was completely confirmed.

Thus one may say with considerable probability that the inclusions, spherical in a general way, are, in their natural position, only facetted on the lower hemisphere.

Detailed Description of the Inclusions.

Observations made on the collected material will now be considered in detail, and attention will be directed to some characteristics of the inclusions as defined by the facets. The normal aspect of these is that of a hemisphere round which the facets are arranged tangentially. Deviations from this type are, however, not uncommon. In a few cases two inclusions are joined by a narrow facetted ridge. Some individuals are collapsed in the middle; less frequently they appear crushed and flattened, the facets being irregularly, though locally, dispersed through the rock, and a few specimens show one inclusion within another.

The facets vary in number and size without regularity, some specimens having as many as fifty. These are often circular, or rudely so, and the contact is imperfect, non-reflecting basalt occupying the spaces and coigns between them (Pl. XVII, Fig. 1). At times the shape is rudely pentagonal or hexagonal, or irregularly polygonal, and in these cases the junction of contiguous facets is frequently a perfectly straight line.

The most striking character of the facets, however, is their crystalline structure, occasionally visible with a hand-lens, but usually requiring observation through a microscope. This phase of the subject has been studied in some detail, and many of the most pronounced features have been photographed in reflected light, using both oblique and vertical illumination. For photographic purposes oblique illumination is somewhat unsatisfactory, as it is almost impossible to use high powers and to get much of the field in focus. These difficulties do not beset the operations when vertical illumination is employed. Nevertheless, for purposes of observation only, the former method is greatly to be preferred.

For convenience of description the observations will be classified as appertaining to the clear, glassy-looking surfaces of the *knobs* and *moulds*[1] (white, blue, or slightly bronze in colour, according to the incidence of the light) and the thin *film* of pronounced bronze colour which separates these surfaces.

[1] The term 'mould' is used in this connexion without any implication that the knob has taken its shape from the mould. The observations, in fact, rather point to the contrary.

The *knob*-facets are characterized by a complex, crystalline structure, sometimes appearing like striation, readily visible under low powers ($\frac{1}{10}$ in. objective), occasionally even with a hand-lens. When well developed this structure seems to be that of a network of felspar crystals, the ends of which, at times, make up the edge of the facet, which has a serrated outline in consequence. On a more minute scale the appearance is that of striation, but this is resolved under higher powers into a crystalline growth similar to the former one, the apparent striation being produced by bundles of parallel, close-fitting shafts. Some surfaces are structureless in parts, others completely crystallized, and the orientation of the crystals varies in different parts of the same facet; a common feature, too, is the intergrowth of two parallel bundles of crystals. The appearances, in general, are very similar to those produced in the laboratory by the crystallization of thin films of material on a flat surface, or between two glass plates.

Some specimens are traversed by wavy cracks from which the crystal-shafts spring, or against which their tooth-shaped ends abut, and when, as sometimes happens, these cracks are curved, they usually enclose a crystallization distinct in direction from the surrounding mass (Pl. XVII, Fig. 2).

The lines of apparent striation can often be resolved, under high powers, into dark, aligned dots, which undoubtedly represent basic matter eliminated in a liquid condition along the sides of the shafts during their crystallization (Pl. XVII, Fig. 6).

When several facets meet with sharp boundaries they are occasionally crossed by bands of crystalline growth, the orientation of which is not altered in passing from one facet to another.

The great complexity and beauty of many of these structural peculiarities will be better realized by reference to the photographs (Plate XVII).

The facets of the *moulds* resemble in detail those of the knobs, but, in addition, they frequently exhibit dark, rectangular and rhomboidal markings or impressions, only one example of which has been met with on the knobs. Sometimes a single facet will show half a dozen such impressions, or again the line of intersection of two facets will cut through one or more (even three) of them, each facet thus claiming part of the impression. The edges of the impressions are frayed at times somewhat in the manner of a skeleton-crystal, and, in one case, the crystalline material enveloping the frayed edges perfects the crude outline of the impression (Pl. XVII, Figs. 1, 3).

These appearances seem to indicate that the impressions are in the nature of negative crystals, produced by local dearth of crystalline material, owing to the contact of the film with the surrounding basalt. Where the contact is imperfect the small amount of intervening crystallizable matter allows of the production of a skeleton-crystal, and the combination of skeletal and negative crystal gives the frayed-edge effect. The comparative absence of rhomboidal impressions on the knobs and their frequent occurrence on the moulds is accounted for by the fact, established by the study of the thin sections, that the knobs (the inclusions proper) consist

in great part of felspar, the crystallization of which in contact with the films is evidently the cause of the surface structures of their facets, while but little felspar usually separates the films from the surrounding whin, so that actual contact is at times inevitable.

The thickness of the crystalline coating of both knobs and moulds is very slight; in fact, the crystallization-phenomena seem to be merely a surface-effect. Scrapings of the coatings appear, by examination in polarized light, to consist of the same felspathic material which is the prime constituent of the inclusions.

The *films*, which part the knob-surfaces and the moulds, have a bronze-yellow, rarely pyritic coloration, becoming olive-green in certain lights. They can be easily scaled off either knob or mould; their thickness is about that of ordinary writing-paper; they are opaque, sink in Sonstadt solution of specific gravity 3·1, are strongly attracted by a bar magnet, and, in fact, show marked polarity.

Both surfaces of the films show crystalline structure, though without correspondence in grouping and orientation, and a similar lack of correspondence exists between the structure of the film-surfaces and those of knob or mould in contact with them. The crystalline markings differ somewhat from those described above, taking the form rather of narrow ridges or troughs, grouped in parallel lines or tufty aggregates, sometimes on either side of an axis (Pl. XVII, Fig. 5).

Minute plates of reflecting mineral found, not infrequently, within inclusions usually exhibit the same structures as the films.

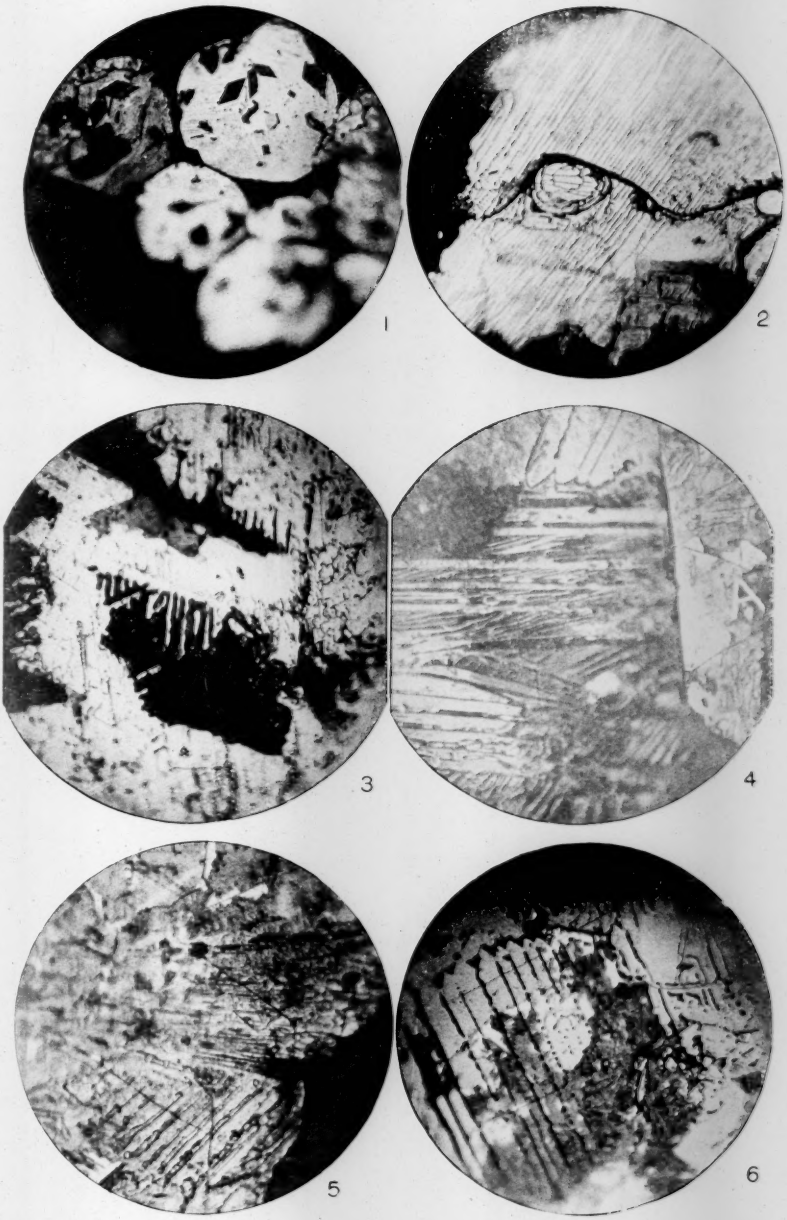
When fragments of the films are digested in warm, fairly concentrated hydrochloric acid they quickly dissolve. The residual powder is non-magnetic, the solution contains ferrous iron and titanium, and the gases evolved respond readily to the tests for hydrogen sulphide. These observations were confirmed on a complete small inclusion; after short immersion in the acid the film was dissolved, disclosing the knob-facets, characteristically marked. Microscopic examination of the films shows them to be sometimes composite, but the above reactions prove that the bronze-coloured mineral is pyrrhotite. It is difficult to say whether the magnetic properties of the films are due only to this mineral or partly to admixture with magnetite, but it is significant that the films in one specimen, which had a pronounced pyritic colour, were devoid of magnetic properties.

The Petrology of the Inclusions.

Thin sections show very considerable differences between the inclusions and the surrounding whin. The latter is normal in character, and the inclusions differ from it, broadly speaking, in being much finer in grain, in the comparative absence of augite, and the presence of a large amount of felspathic material and some quartz.

Of the mineral constituents, felspar greatly predominates, and oxides of iron appear more plentiful, as a rule, than in the normal whin, despite the smaller yield on analysis. This is to be explained by the rarity of augite, nearly all the iron being visible in the form of opaque minerals.

The felspar exists in two forms; in groups of well-crystallized individuals, like those in the normal whin, though at times with the



Microphotographs of surfaces of inclusions from the Great Whin Sill of Northumberland.

twinning less developed; and as patches showing spherulitic structure. These spherulites have a brownish tinge and form a highly characteristic component of the inclusions. They have been the last material to consolidate, they are often gathered round a cluster of felspar crystals, or a single individual, and they sometimes show a tendency to assume the outlines of a felspar crystal.

Quartz is a common constituent of the inclusions, and occurs both in interstitial and idiomorphic forms; it is most abundant at the edges of the spherulites and is often penetrated by felspar. There are several opaque iron-minerals present. One has a bronze colour and occurs in roundish plates and long slender bands; another is bluish-black and occasionally shows, in reflected light, a structure like that of the films. Sections cut vertically through the films often show these two minerals, side by side, sometimes fringed with a third, dull, non-reflecting mineral; and when the section makes a low angle with the film the dull mineral is seen to be entirely in the skeletal condition. The films are thus sometimes composite, and appear to consist of pyrrhotite and magnetite, possibly with a little titaniferous oxide, and these minerals also occur irregularly distributed throughout the inclusions. In addition to these some of the slides also show a few scattered crystals of ilmenite which exhibit the characteristic cinnamon-brown colour.

Apatite is the only accessory mineral identified with certainty. It occurs, with moderate frequency, in well-developed crystals with dark centres, and also in the form of bundles of long, but exceedingly slender, needles. These are very abundant in all the sections, and undoubtedly contribute greatly to the high phosphorus-content established by analysis. They penetrate all the other constituents except the iron-minerals.

Most of the slides show small amygdules, fringed with iron-oxide and filled with secondary quartz and calcite. This confirms the observations made on hand-specimens as to the frequency of occurrence of amygdules in the inclusions. Another observation, mentioned above, concerning the contact of the films, finds support from the study of the sections; for it is found that adjacent films sometimes meet at a sharp angle, and are sometimes separated for some little distance, the intervening space being occupied by the materials peculiar to the inclusions.

With respect to the relations between the inclusions and the surrounding basalt, the study of the slices yields some rather unexpected results. Though the petrological contrast of the rocks is considerable, the contact is never clearly marked. The general shape of the inclusions in the sections is circular, but the edges are somewhat wavy in outline, owing to interpenetration of the components of each rock-species. Generally speaking, it may be stated that the lower the magnification the better is the definition of the inclusions.

Again, though in hand-specimens half of an inclusion is quite sharply defined by the films, the latter never constitute boundaries in the sections; there is practically always some felspathic material on the outside of the films, even though the thickness of this is, at times,

slight. This is clearly the material which gives the crystallization-phenomena of the mould-surfaces.

The occurrence of concentric inclusions, noted above, is borne out by the sections. In one prominent example the inner inclusion is largely made up of spherulites, while the material of the enveloping inclusion is of greater variety and shows a more advanced stage of crystallization.

Mention may be made here of some smooth, roundish masses which occur along with the inclusions, and differ from them externally in the absence of bright facets and films and by a slight, but distinct, surface-sheen. Sections of these have all the characters of the inclusions proper, and, in some cases, actually enclose them. Though distributed sparingly, they evidently belong to the same order of phenomena as the inclusions.

The Chemistry of the Rocks.

For the purposes of chemical examination several inclusions, or, more accurately, their facetted hemispheres, were isolated as completely as possible, and a fairly large sample of the whin immediately surrounding them was also taken. Both samples were coarsely crushed, sieved free from dust, then ground and dried at 110° C. Total iron in each case is reckoned as ferrous oxide. The analytical data are given below in columns I and II, those for the whin being the mean values of closely-agreeing duplicates. Some other analyses (in which the iron is recalculated as ferrous oxide) are given in the table (columns III, IV, and V) for the sake of comparison; they will be dealt with later.

	I.	II.	III.	IV.	V.
SiO_2 . .	49·54	58·10	61·18	58·29	57·80
Al_2O_3 . .	16·64	14·49	19·95	14·74	16·18
TiO_2 . .	2·84	1·65	—	—	—
FeO . .	11·44	9·51	3·20	9·36	9·00
MnO . .	0·20	0·16	—	0·27	—
CaO . .	9·00	5·05	5·45	6·93	6·18
MgO . .	5·51	3·32	0·92	4·17	4·68
K_2O . .	0·97	2·36	2·83	1·53	0·77
Na_2O . .	2·33	2·76	4·70	2·71	2·38
P_2O_5 . .	0·28	0·73	—	—	—
CO_2 . .	0·16	1·61	1·13	0·30	1·70
H_2O . .	0·47			1·35	
	99·38	99·74			
S.G. . .	2·900	2·725	2·67–2·70	2·770	2·810

I. Whin Sill surrounding inclusions, Snook Point.
II. Inclusions, Snook Point.
III. Felspars from Whin Sill, Caldron Snout (analysis by Teall).
IV. Cleveland Dyke (mean of three analyses by Stead and Stock).
V. Acklington Dyke (analysis by Stead).

The figures for the rock surrounding the inclusions (No. I) agree very closely with Teall's analyses of the Whin Sill from Borcovicus and Caldron Snout,[1] and they afford fresh evidence of the uniformity

[1] Quart. Journ. Geol. Soc., vol. xl, p. 654, 1884.

in composition of that great mass of intrusive rock; in addition they show that the peculiarities of the inclusions are not due to local variation in the sill as a whole.

Comparing the analyses I and II, it will be seen that silica and the alkalies have increased in the inclusions at the expense of iron, lime, and magnesia, and of the alkalies, potash has increased to a greater extent than soda. The relations between the whin and the inclusions are thus precisely those which have been proved to exist in rocks of andesitic composition between the rock as a whole and its glassy base or groundmass.[1]

This relationship points to a genetic connexion between the rocks. Assuming for the moment that such exists, then the decrease in iron is much smaller than has been usually observed. Such differences may, however, be expected, since the Whin Sill is more basic than the rocks which have been studied in this light, and there is possibly some difference in the order of crystallization in the two cases.

From the simultaneous decrease in titanium and iron it might be inferred that the former is present, to some extent at least, as ilmenite, as proved by Teall in the rock of Caldron Snout; but as the decrease is not by any means proportionate, and as augite is rare in the inclusions, it would appear that some of the titanium in the whin was included in the augite.

The distribution of phosphorus, in cases such as those we are dealing with, is a question to which but little attention has been paid, though it is one of some interest owing to the position of apatite in the order of crystallization of minerals from magmas. The analyses show a very considerable enrichment in phosphorus in the inclusions. Assuming the phosphorus in the rocks to be present as chlorapatite, then the whin contains 0·68 per cent and the inclusions 1·78 per cent of that mineral. The inclusions thus contain 2·6 times as much apatite as the whin, though one might expect the order to be reversed corresponding to the greater acidity of the inclusions.

There is a general resemblance in composition between the felspars isolated from the Whin Sill by Teall (see column III) and the inclusions, the chief difference being in the iron. If we imagine the felspars mixed with 7 per cent of iron oxide, then the resulting material would be very similar in composition to the inclusions. It may be noted, too, that the ratio of the oxides (Na_2, K_2) O : Ca O in the inclusions (1 : 1·3) is not far different from that in the felspars (1 : 1).

Before leaving the discussion of the analyses it may be pointed out that while the Whin Sill resembles in composition the dykes of Hett, Collywell, Crookdene, and Morpeth, the inclusions are very similar in composition to the Cleveland and Acklington dykes, as may be seen by comparison of columns II, IV, and V in the table above. There are indications here of an association analogous to that observed in Skye, where dykes of augite-andesite, similar in composition to the Acklington and Cleveland dykes, frequently

[1] See J. J. H. Teall, *British Petrography*, 1888, pp. 42, 43, also, among others, J. W. Judd, Q.J.G.S., 1890, p. 341; 1893, p. 536; and A. Harker, *The Tertiary Igneous Rocks of Skye*, 1904, pp. 331, 339.

contain vesicles and kernels of thoroughly acidic composition, and are associated in the same area with dykes of acidic pitchstone.[1]

The Origin of the Inclusions.

The observations described in the foregoing pages throw some light on the origin of the inclusions, though many of the deductions are necessarily of a somewhat speculative nature, and some of the difficulties are probably incapable of solution by the data at present available. The three main aspects of the problem are: how was the material of the inclusions generated, how did it get into its present position, and by what process did the inclusions acquire their form and characteristic facetting?

With regard to the first point, there is nothing to indicate that the inclusions represent foreign material, igneous or sedimentary, which has been caught up by the whin during intrusion; and the evidence, both chemical and petrological, makes it clear that local variation of the whin as a whole is not at the root of the matter. In the lack of definition, or of sharp contact between the inclusions and the surrounding rock, and in the absence of tangentially-arranged felspars around them, the inclusions differ from the glass-filled amygdules of many of the local dykes,[2] and thus their material cannot be regarded as a differentiation-product of the whin, produced in situ by the process of crystallization, and concentrated locally by injection into amygdaloidal cavities.

That the material has been derived from the whin, however, by some process of fractionation seems evident from its associations, its likeness in composition to the felspars, which are the early crystallization-products from that magma, and especially by the chemical relationship it bears to that rock.

In view of these considerations and also of the field-relationships, the lower specific gravity of the inclusions, and the very frequent occurrence in them of amygdaloidal cavities, it seems inevitable to conclude that the material of the inclusions is derived from the whin and has floated upwards into its present position from its source below.

Now at this place the whin forms a comparatively thin sill, so that one must further assume the sill to be connected with a deep-seated source of supply. The suggestion is thus made that the Whin Sill at Snook Point is directly connected with a feeder of some sort; that the sill itself is composite in the sense that several successive injections of magma have taken place; and that after the final injection, and before its consolidation, small masses of magma, specifically lighter, of different composition, and possibly buoyed up by gas-bubbles, floated up the feeder and became entrapped in the viscous basalt of the last-injected sheet, in the immediate neighbourhood of the feeder, and in the feeder itself.

This hypothesis accounts satisfactorily for many peculiarities in the mode of occurrence of the inclusions, as, for example, their restricted range to the dyke-like portion of the rock and the sheet

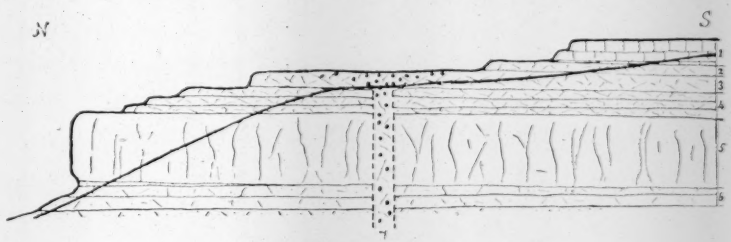
[1] A. Harker, *The Tertiary Igneous Rocks of Skye*, 1904, p. 402.

[2] J. J. H. Teall, GEOL. MAG., Dec. III, Vol. VI, p. 481, 1899. M. K. Heslop & J. A. Smythe, Q.J.G.S., vol. lxvi, p. 1, 1910.

with which this appears to blend, the numbers being greatest immediately over the feeder, and falling off on either side of it (Figure). The general spherical character of the inclusions and the lack of sharp boundaries between them and the surrounding rock are explicable as the results of two opposing tendencies—surface-tension, promoting a spherical drop-like form, and diffusion, tending to the blending of the magmas and the establishment of uniform composition.

There are two questions arising out of the hypothesis which require consideration; the first is relative to the feeders of the Whin Sill, the second concerns the differentiation-process.

With regard to the first there appears to be no positive evidence. Thus Professor Lebour and his collaborators write: "Up to the present time no whin dyke has ever been proved to belong to, cut through, or come in contact with, the Great Whin Sill."[1] And again: "The relation which the whin dykes of the district bear to the Whin Sill is an interesting question; but it is one upon which little can be said. There is no certain case in Northumberland of



SECTION AT SNOOK POINT.

Illustrating disposition of Whin Sill and inclusions and the hypothetical dyke-feeder. (Below the heavy continuous line the section is diagrammatic; the portion which can be observed lies above this line.)

1. Great Limestone.
2. Fine-grained whin, without amygdules, altered at contact with limestone.
3. Bedded whin, with amygdules and inclusions.
4. Bedded whin, with amygdules.
5. Columnar whin, altered at contact with sedimentary beds.

WHIN SILL, about 25 feet thick.

6. Carboniferous sandstone.
7. Hypothetical dyke-feeder of whin, containing inclusions (black dots).

a whin dyke intersecting the Whin Sill."[2] So far as the writer is aware these words adequately express the state of our knowledge on the subject at the present day; visual proof of connexion at Snook Point is not to be expected, owing to the limited exposure on the foreshore and the thick cover of blown sand on the adjacent land.

With respect to the differentiation-process, it would appear that

[1] G. A. Lebour & Mark Fryer, "On the Harkess Rocks, near Bamburgh": North of England Institute of Mining and Mechanical Engineers, vol. xxvi, p. 1, 1877.

[2] W. Topley & G. A. Lebour, "On the Intrusive Character of the Whin Sill of Northumberland": Q.J.G.S., vol. xxxiii, p. 406, 1877.

the inclusions represent a primary crystallization of the magma, consisting, as they do, so largely of felspar, closely allied in composition to that of the Whin Sill (from which it is the first mineral to crystallize in quantity), and abounding in apatite, one of the earliest of the minerals to separate from the magma. This case, therefore, resembles in some degree that whereby the anorthite inclusions of the Crookdene group of local dykes were formed.[1] Both are products of early crystallization, but whereas the anorthite in the dykes crystallized under plutonic conditions and was floated up in a solid state, the inclusions evidently came into position in a liquid form, or at most with the iron minerals consolidated. Differentiation in the latter case has thus been effected either in the liquid magma, or an early solid product of the process has been remelted owing to some change in condition.

The interpretation of the salient characteristics of the inclusions, viz. the facetting and crystallization-phenomena, presents many difficulties and uncertainties. The beautifully marked surfaces are clearly the result of the crystallization of material, mainly felspathic, in contact with the plane surfaces of the films, and the proof from the thin sections that this material lies on both sides of the film explains the similarity in appearance of both knobs and moulds. The corollary to this view is that the pseudo-crystal form of the inclusions is determined by the arrangement of the film-plates in a liquid medium.

If full credit be given to observations made in the field and laboratory, that only the lower hemisphere of an inclusion in its natural position is facetted, then one of the formative factors would appear to be the settling, under gravity, of the heavy already fashioned films of iron minerals in a molten matrix. The only other recognizable directive force which may have been operative in arranging the plates is magnetic; for, as already stated, the films show well-defined magnetic polarity and when suspended in a slightly denser liquid would slowly sink and arrange themselves end on end. Such a process might be helped by the crystallization of the apatite, the crystals of which, forming a kind of network, would help to keep the shell of films near the boundaries of the inclusion. However produced, such fragile structures would be very unstable, and the slightest movement in the rock would cause their collapse, malformation, or even obliteration.

All of these effects can be noted in the specimens and thus add support to the view, though the difficulties in the way of its acceptance are so great that the suggestion must be regarded only as a crude working hypothesis, which may possibly serve its purpose in the elucidation of the prime difficulty—the origin of the mock-crystal structure of the inclusions.

In conclusion, the author wishes to express his cordial thanks to Professor Lebour for his encouragement and interest in this work, and to W. M. Hutchings, Esq., for his valuable help in the examination of the rock sections.

[1] M. K. Heslop & J. A. Smythe, "The Dyke at Crookdene," etc.: Q.J.G.S., vol. lxvi, p. 1, 1910.

EXPLANATION OF PLATE XVII.

The six microphotographs reproduced in this Plate are taken by *reflected* light, and illustrate the crystallization-phenomena of the plane surfaces or facets which bound the inclusions.

FIG. 1. Group of roundish mould-facets showing rhomboidal impressions. Oblique illumination, magnified 8 diameters.
,, 2. Knob-facet, with curved cracks and pseudo-striation. Oblique illumination, magnified 22 diameters.
,, 3. Mould-facet, with highly magnified, rhomboidal impression showing frayed edge. The perfecting of the outline of the impression in the enveloping crystalline material can be faintly seen, as shown by the white crosses.
,, 4. Knob-facet showing crystalline structure. A fragment of film is marked A.
,, 5. Structure of film, a portion of which is shown in Fig. 4 (marked A).
,, 6. Knob-facet showing crystal-shafts and resolution of pseudo-striation into aligned dots.

Figs. 3–6, vertical illumination, magnified 110 diameters.

II.—The Foraminifera of the Speeton Clay of Yorkshire.

By R. L. Sherlock, D.Sc., A.R.C.Sc., F.G.S.

(PLATES XVIII AND XIX.)[1]

(*Continued from the May Number, p. 222.*)

Family LAGENIDÆ.

Sub-family LAGENINÆ.

LAGENA, Walker & Boys.

Lagena globosa (Montagu). (Pl. XVIII, Fig. 6.)

Vermiculum globosum, Montagu, 1803 : Test. Brit., p. 523.
Entosolenia globosa, Reuss, 1862 : Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 318, pl. i, figs. 1–3.
Lagena globosa, Burrows, Sherborn, & Bailey, 1890 : Journ. Roy. Micr. Soc., p. 555, pl. ix, figs. 1, 2, 4.

Remarks.—This species has been recorded in rocks as old as the Wenlock Limestone and shale (Brady), and is still living in almost every depth of water and in all latitudes.

Horizon.—Present in C_1, C_2, C_{10}. One specimen from each bed.

Lagena apiculata, Reuss. (Pl. XVIII, Fig. 12.)

Lagena apiculata, Reuss, 1862 : Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 319, pl. i, figs. 4–8, 10, 11.

Remarks.—*L. apiculata* is known from various formations from the Lias to the Recent. It is still abundant in both shallow and deep water. It is noteworthy that the specimens from C_1 and C_{10} are very large (see Pl. XVIII, Fig. 12).

Horizon.—Found in B base *c*, C_1, ? C_9 (broken specimen), C_{10}. One from each horizon.

[1] Plate XIX will appear in the July Number with the concluding part of the author's paper.

Lagena apiculata, var. *danfordi*, var. nov. (Pl. XVIII, Fig. 8.)

Test elongated, pointed at both ends, slightly oviform in cross-section. The narrower side is straight, the wider curving towards it at the ends. The base tapers rapidly to a point, the oral end is bluntly pointed. Length about ·475 mm. (·018 in.), greatest diameter ·095 mm. (·0037 in.). It resembles most nearly the figure of *L. apiculata* in Burrows, Sherborn, & Bailey's paper on the Red Chalk (pl. ix, fig. 6), but the three specimens found all agree in having both ends of the test in the same straight edge. The variety has been named after Mr. C. G. Danford, to whom, as already mentioned, I am indebted for the specimens of Speeton Clay which I have examined.

Horizon.—Found in Upper C_2. Three specimens.

Lagena lævis (Montagu). (Pl. XVIII, Fig. 14.)

Vermiculum lævе, Montagu, 1803 : Test. Brit., p. 524.
Lagena lævis, Brady, 1884 : Chall. Rep., vol. ix, p. 455, pl. lvi, figs. 7–14, 30.
L. lævis, Burrows, Sherborn, & Bailey, 1890 : Journ. Roy. Micr. Soc., p. 555, pl. ix, fig. 3.

Remarks.—This is probably the commonest and most widely distributed of the *Lagenæ*, and has been recorded from the Woolhope Beds. At present it occurs at all depths down to at least 2,435 fathoms (Chall. Rep.).

Horizon.—Found in B base *c*. Several specimens.

Sub-family NODOSARIINÆ.

Nodosaria, Lamarck.

Sub-genera Glandulina and Dentalina, d'Orbigny.

Nodosaria (*G.*) *lævigata*, var. *strobilus*, Reuss. (Pl. XVIII, Fig. 11.)

Glandulina lævigata, var. *strobilus*, Reuss, 1870 : Sitzungsb. d. k. Ak. Wiss. Wien, vol. lxii, p. 477 ; Schlicht, Foram. Pietzpuhl, 1870, pl. vi, figs. 15, 16.

Remarks.—The forms of *Nodosaria* are very variable, and the specimen found does not differ much from *N. mutabilis*, Reuss, figured in his paper on the Foraminifera of the Hils (pl. v, figs. 9–11). It is noteworthy that the earlier sutures are oblique, a condition regarded by Reuss as of generic importance when he founded the genus *Psecadium* (Sitzungsb. d. k. Ak. Wiss. Wien, vol. xliv, p. 368, 1861). The variety has been recorded from the Tertiary Septaria-clay of Pietzpuhl.

Horizon.—One specimen only from C_{10}.

Nodosaria hispida, d'Orbigny. (Pl. XVIII, Fig. 18.)

Nodosaria hispida, d'Orbigny, 1846 : For. Foss. Vien., p. 35, pl. i, figs. 24, 25.
N. conspurcata, Reuss, 1863 : Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlviii, p. 43, pl. ii, figs. 10–14.
N. hispida, Brady, 1884 : Chall. Rep., vol. ix, p. 507, pl. lxiii, figs. 12–16.

Remarks.—The species is known from the Middle and Upper Lias of the West of England (Brady, Walford), the Chalk of Ireland

(Wright), the London Clay (Jones & Parker), the Tertiary Septaria-clays of Hermsdorf and Pietzpuhl (Reuss), etc., and was found by the *Challenger* Expedition at depths of from 95 to 450 fathoms.

Horizon.—One broken specimen from B base *b*.

Nodosaria calomorpha, Reuss. (Pl. XVIII, Fig. 16.)

Nodosaria calomorpha, Reuss, 1865: Denkschr. d. k. Ak. Wiss. Wien, vol. xxv, p. 129, pl. i, figs. 15–19.

N. (*Dentalina*) *consobrina*, Parker & Jones, 1865: Phil. Trans., vol. clv, p. 342, pl. xvi, fig. 3.

N. calomorpha, Terrigi, 1880: Atti dell'Accad. Pont., ann. xxxiii, p. 178, pl. i, fig. 7.

N. calomorpha, Brady, 1884: Chall. Rep., vol. ix, p. 497, pl. lxi, figs. 23–7.

Remarks.—One specimen found has three chambers, the others but two, and they differ in the relative width of the chambers, resembling in this respect the figures of Parker & Jones and Terrigi. The species has been described from Tertiary beds by Reuss and Terrigi, and is present in the Atlantic and Pacific Oceans at depths varying from 6 to 2,200 fathoms (Brady).

Horizon.—Found in B base *c*. Several specimens.

Nodosaria (*Dentalina*) *siliqua* (?), Reuss. (Pl. XVIII, Fig. 19.)

Dentalina siliqua, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 40, pl. ii, fig. 11.

Remarks.—A damaged specimen agrees rather closely with Reuss' figure, but the upper part is broken away. It has been recorded by Reuss from the highest bed of the German Hils and from the Plänerr.

Horizon.—Found in B base *c*. One specimen.

Nodosaria (*Dentalina*) *fontannesi*, Berthelin. (Pl. XVIII, Fig. 7.)

Dentalina fontannesi, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 42, pl. ii, fig. 14.

N. (*D.*) *fontannesi*, Chapman, 1893: Journ. Roy. Micr. Soc., p. 593, pl. ix, fig. 15.

Remarks.—The species is described from the Gault of France and Folkestone by Berthelin and Chapman respectively.

Horizon.—Found in Upper C_2. One specimen.

Nodosaria (*Dentalina*) *lorneiana*, d'Orbigny. (Pl. XVIII, Fig. 13.)

Dentalina lorneiana, d'Orbigny, 1840: Mém. Soc. géol. France, vol. iv, p. 14, pl. i, figs. 8, 9.

Nodosaria lorneiana, Reuss, 1845: Verstein. böhm. Kreideform., vol. i, p. 27, pl. viii, fig. 5.

N. (*D.*) *lorneiana*, Chapman, 1893: Journ. Roy. Micr. Soc., p. 588, pl. viii, figs. 30, 31.

Remarks.—The species is recorded from the Folkestone Gault (Chapman), the Bohemian Cretaceous (Reuss), and the Lower Chalk of Dover (Jones). It seems probable that *N. nuda*, Reuss (Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 38, pl. ii, figs. 8, 9, 1862), is the same species, and if so the form occurs in the Gault of North Germany.

Horizon.—Found in Upper C_2. Two specimens.

Nodosaria (*Dentalina*) *legumen*, Reuss. (Pl. XVIII, Fig. 22.)

Nodosaria (*Dentalina*) *legumen*, Reuss, 1845: Verstein. böhm. Kreideform., pt. i, p. 28, pl. xiii, figs. 23, 24.

D. legumen, Reuss, 1860: Sitzungsb. d. k. Ak. Wiss. Wien, p. 187, pl. iii, fig. 5.

Remarks.—This form has been recorded from the Gault of Folkestone (Chapman), of France (Berthelin), and the Rhine (Reuss), and from the Cretaceous of Bohemia and Hanover (Reuss). Brady (Chall. Rep., vol. ix, p. 504) considers it to be the same as *N. communis*, d'Orb., which has at present a worldwide range.

Horizon.—Found in B base *c*. One specimen.

Nodosaria (*Dentalina*) *communis*, d'Orbigny. (Pl. XVIII, Fig. 24.)

Nodosaria (*Dentalina*) *communis*, d'Orbigny, 1826: Ann. Sci. Nat., vol. vii, p. 254, No. 35.

N. (*D.*) *communis*, Brady, 1884: Chall. Rep., vol. ix, p. 504, pl. lxii, figs. 19–22.

N. (*D.*) *communis*, Chapman, 1893: Journ. Roy. Micr. Soc., p. 590, pl. ix, fig. 1.

Remarks.—The species is known from many deposits above and below the Cretaceous System (Chapman). Its present distribution is worldwide, and it is found at almost any depth.

Horizon.—Found in Upper C_2. One specimen.

Nodosaria (*Dentalina*) *roemeri*, Neugeboren. (Pl. XVIII, Fig. 9.)

Dentalina roemeri, Neugeboren, 1856: Denkschr. d. k. Ak. Wiss. Wien, vol. xii, p. 82, pl. ii, figs. 13–17.

D. nana, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 39, pl. ii, figs. 10, 18.

N. (*D.*) *roemeri*, Chapman, 1893: Journ. Roy. Micr. Soc., p. 589, pl. viii, fig. 38.

Remarks.—Recorded from the Upper Hils and Gault of North Germany (Reuss), the Gault of Northern France (Berthelin) and Folkestone (Chapman); the species is still living at depths of not more than 400 fathoms (Brady).

Horizon.—Found in Upper C_2. One specimen.

Frondicularia, Defrance.

Frondicularia gaultina (?), Reuss. (Pl. XIX, Fig. 11.)

Frondicularia gaultina, Reuss, 1860: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xl, p. 194, pl. v, fig. 5.

Remarks.—A broken specimen probably belongs to this species. The base is missing, but the shell resembles Reuss' figure fairly closely. The species is recorded from the *Minimus*-clay of the Rhine (Reuss), the Red Chalk of Speeton (Burrows, Sherborn, & Bailey), and the Folkestone Gault (Chapman).

Horizon.—Found in Upper C_2. One specimen.

Rhabdogonium, Reuss.

Rhabdogonium insigne, Reuss. (Pl. XVIII, Fig. 21.)

Rhabdogonium insigne, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 56, pl. v, fig. 2.

Remarks.—Reuss describes this species as very rare in the Upper

Hils to the north-west of Berklingen, and it does not seem to have been recorded since.

Horizon.—Found in D_6 mid. Several specimens.

MARGINULINA, d'Orbigny.

Marginulina linearis, Reuss. (Pl. XVIII, Fig. 10.)

Marginulina linearis, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 60, pl. v, fig. 15.
M. linearis, Chapman, 1894: Journ. Roy. Micr. Soc., p. 161, pl. iv, fig. 14.

Remarks.—Reuss' figure shows seven chambers and Chapman's six, whereas the specimen found has only four. The species is recorded from the *Minimus*-clay of North Germany (Reuss), the Gault of Northern France (Berthelin) and Folkestone (Chapman).

Horizon.—Present in Upper C_2. One specimen.

Marginulina glabra, d'Orbigny. (Pl. XVIII, Fig. 17.)

Marginulina glabra, d'Orbigny, 1826: Ann. Sci. Nat., vol. vii, p. 259, No. 6; Modèle No. 55.
M. inæqualis, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 59, pl. v, fig. 13.

Remarks.—The specimen is more curved than usual, but in other respects agrees with *M. glabra*. The species is recorded from the *Minimus*-clay of Germany (Reuss), the Red Chalk of Speeton (Burrows, Sherborn, & Bailey), the Folkestone Gault (Chapman), and is still living (Brady) in both shallow and deep water.

Horizon.—Found in B base *c*. One specimen.

Marginulina jonesi, Reuss. (Pl. XVIII, Fig. 15.)

Marginulina jonesi, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 61, pl. v, fig. 19.
M. jonesi, Chapman, 1894: Journ. Roy. Micr. Soc., p. 163, pl. iv, fig. 24.

Remarks.—This is much the commonest species of *Marginulina* in the Speeton Clay, and is fairly abundant. The individuals differ considerably, one specimen (in D_6) showing a passage to *M. striato-costata*, Reuss, which Brady regards as synonymous with *M. costata*, Batsch. In fact, *M. jonesi* is a mere variety of *M. costata*, characterized by fewer and more marked ribs. Other specimens pass into *M. robusta*, Reuss. *M. jonesi* has been recorded from the Upper Hils of Germany and by Chapman from the Folkestone Gault.

Horizon.—Found in B base *b*, Upper C_2, and D_6 mid. Fairly abundant.

Marginulina debilis, Berthelin. (Pl. XVIII, Fig. 23.)

Marginulina debilis, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 35, pl. iii, fig. 28.
M. debilis, Chapman, 1894: Journ. Roy. Micr. Soc., p. 161, pl. iv, fig. 15.

Remarks.—The only specimen found agrees with Chapman's figure in possessing only five chambers. The species is known from the Gault of France (Berthelin) and of Folkestone (Chapman).

Horizon.—Found in Upper C_2. One specimen.

VAGINULINA, d'Orbigny.

Vaginulina incompta (?), Reuss. (Pl. XIX, Fig. 10.)

Vaginulina incompta, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 45, pl. iii, fig. 5.

Remarks.—One specimen probably belongs to this species. The initial cell is rather small and the chambers are somewhat more obliquely set than in Reuss' figure. He describes it as very rare in the Upper Hils Clay at Glückauf.

Horizon.—Found in Upper C_2. One specimen.

Fragments of other species of *Vaginulina* have been found in B base *c*, Upper C_2, and D_6 mid, but too imperfect for specific determination.

CRISTELLARIA, Lamarck.

Cristellaria gracillissima, Reuss. (Pl. XVIII, Fig. 26.)

Cristellaria gracillissima, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 64, pl. vi, figs. 9, 10.

Remarks.—The specimens vary greatly in length and the extent to which the spiral part is developed; some have scarcely any spiral commencement and are very close to *C. fœda*, Reuss (op. cit., p. 64, pl. vi, figs. 11–13). There can be little doubt that the two forms are really one species, and that *fœda* should be dropped as a specific name. It is possible that the form figured by G. R. Vine from the Cambridge Greensand as ? *Trochammina helvetico-jurassica*, Hausler (Proc. Yorks. Geol. Polytech. Soc., N.S., vol. ix, pt. i, p. 28, pl. ii, fig. 16, 1885 (1886)), is *C. gracillissima*. There is a resemblance in the outline of the shell and the mouth, and *C. gracillissima* in some cases appears to have an arenaceous test, owing to the rough prickly surface. The small side-chamber in Vine's figure is, however, very difficult to account for on this hypothesis.

Viewed as a transparent object, the rough surface of *C. gracillissima* is seen to be due to the outgrowths of calcite in optical continuity with the shell.

Horizon.—Common in B base *c*.

Cristellaria acutauricularis (Fichtel & Moll). (Pl. XIX, Fig. 2.)

Nautilus acutauricularis, Fichtel & Moll, 1803: Test. Micr., p. 102, pl. xviii, figs. *g–i*.

Cristellaria polita, Reuss, 1855: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xviii, p. 237, pl. iii, fig. 41.

C. acutauricularis, Brady, 1884: Chall. Rep., vol. ix, p. 543, pl. cxiv, figs. 17*a*, *b*.

Remarks.—The Cristellarians are (with the exception of *Pulvinulina caracolla*) the commonest of all the Foraminifera in the Speeton Clay, and offer great difficulties in specific determination, since no two specimens are quite alike and the number of described species is very great. Figures of the same species given by different authorities differ widely. A number of specimens seem certainly referable to *C. acutauricularis*, whose range in time extends at least as far back as the Lias. The species has been recorded from that formation by

Crick & Sherborn (Journ. Northants. Nat. Hist. Soc., 1891, p. 5, pl., fig. 25), and it is still living. The *Challenger* Expedition found it at depths of from 95 to 2,750 fathoms.

Horizon.—Present in B base *c*, C_1, and D_6 mid. Fairly abundant.

Cristellaria gibba, d'Orbigny. (Pl. XIX, Fig. 9A, B.)

Cristellaria gibba, d'Orbigny, 1839: Foram. Cuba, p. 63, pl. vii, figs. 20, 21.
C. nuda, Reuss, 1861: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xliv, p. 328, pl. vi, figs. 1–3.
C. pulchella, Reuss, 1862: ibid., vol. xlvi, p. 71, pl. viii, fig. 1.
C. gibba, Chapman, 1896: Journ. Roy. Micr. Soc., p. 4, pl. i, figs. 7*a*, *b*.

Remarks.—This species is closely allied to *C. acutauricularis* and has the same range in time. It is recorded from the Upper Hils Clay of Germany (Reuss), the Gault of Folkestone (Chapman), and the Bargate Beds (Lower Cretaceous) of Surrey (Chapman), and from the Red Chalk of Speeton (Burrows, Sherborn, & Bailey). The *Challenger* Expedition found it at depths of less than 500 fathoms.

Horizon.—Present in Upper C_2, Upper C_3, C_{10}. Common in Upper C_2, one specimen from each of the other horizons.

Cristellaria cephalotes, Reuss. (Pl. XVIII, Fig. 20.)

Cristellaria cephalotes, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 67, pl. vii, figs. 4–6.

Remarks.—A single, very thick specimen seems to belong to this species. It has been recorded by Reuss from the Upper Hils and the *Minimus*-clay of Germany.

Horizon.—Found in B base *b*. One specimen.

Cristellaria scitula, Berthelin. (Pl. XIX, Fig. 5.)

Cristellaria scitula, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 53, pl. iii, figs. 3*a*–*c*.
C. scitula, Chapman, 1894: Journ. R. Micr. Soc., p. 652, pl. x, figs. 7*a*, *b*.

Remarks.—This species has been recorded by Berthelin and Chapman in the Gault of Northern France and Folkestone.

Horizon.—One specimen was found in B base *c*.

Cristellaria chapmani, sp. nov. (Pl. XIX, Fig. 7A, B.)

Description.—Test suboval, with nearly flat sides. It consists of about six chambers, arched, and divided by marked sutural ridges which end abruptly in front, and, near the back, end in a ridge parallel with the dorsal edge. The spiral commencement is obscure. There is no umbilicus. The dorsal edge is smoothly curved, and there is a keel about equally developed with the ridges following the dorsal edge. The aperture is terminal. Length about ·492 mm. (·0194 in.), greatest breadth ·304 mm. (·012 in.).

The form is nearest to *C. bradyana*, Chapman (Journ. Roy. Micr. Soc., 1894, p. 654, pl. x, figs. 13*a*, *b*). It has, however, fewer chambers, the sutural ridges and the dorsal edge are not sinuous, and the dorsal ridges are as well developed as the small keel.

I have named this species after Mr. Frederick Chapman in

recognition of the kindly assistance he has always given me in work on the Foraminifera.

Horizon.—Found in B base *c* and Upper C_2. Fairly abundant at both horizons.

Cristellaria crepidula (Fichtel & Moll). (Pl. XIX, Fig. 8.)

Nautilus crepidula, Fichtel & Moll, 1803: Test. Micr., p. 107, pl. xix, figs. *g–i*.
Cristellaria grata, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 70, pl. vii, fig. 14.
C. crepidula, Brady, 1884: Chall. Rep., vol. ix, p. 542, pl. lxvii, figs. 17, 19, 20; pl. lxviii, figs. 1, 2.
C. crepidula, Jos. Wright, 1886: Proc. Belfast Nat. Field Club, App., p. 331, pl. xxvii, fig. 4.

Remarks.—The species ranges from the Lias to Recent. It is recorded (as *C. grata*) by Reuss from the Upper Hils and the *Minimus*-clay of Germany, from the Folkestone Gault by Chapman, the Red Chalk of Speeton by Burrows, Sherborn, & Bailey, and from the Bargate Beds (Lower Cretaceous) of Surrey by Chapman. One specimen agrees most closely with Wright's figure quoted above.

Horizon.—Found in B base *c* (a few specimens) and one specimen from Upper C_2.

Cristellaria turgidula, Reuss. (Pl. XIX, Fig. 1.)

Cristellaria turgidula, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 73, pl. viii, figs. 4*a*, *b*.
C. ingenua, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 54, pl. iii, figs. 20, 21.
C. turgidula, Chapman, 1896: Journ. Roy. Micr. Soc., p. 1, pl. i, fig. 1.

Remarks—The form is recorded by Reuss from the *Milletianus*- and *Minimus*-clays of Germany, and from the Gault of Northern France and Folkestone by Berthelin and Chapman.

Horizon.—Present in C_1 and Upper C_2. One specimen from C_1, two from C_2.

Cristellaria cultrata (Montfort). (Pl. XIX, Fig. 4.)

Robulus cultratus, Montfort, 1808: Conchyl. Système, vol. i, p. 214, 54e genre.
Cristellaria cultrata, Brady, 1884: Chall. Rep., vol. ix, p. 550, pl. lxx, figs. 4–6.

Remarks.—A specimen from D_2 base is intermediate between *C. cultrata* and *C. rotulata*. The species is known from the Lias and successive formations to Recent times. Brady states that, as a rule, *C. cultrata* is rarely met with at a depth of less than 100 fathoms.

Horizon.—Found in D_6 mid and ? D_2 base. One specimen in each case.

Cristellaria gaultina, Berthelin. (Pl. XVIII, Fig. 27.)

Cristellaria gaultina, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 49, pl. iii, figs. 15–19.
C. gaultina, Chapman, 1896: Journ. Roy. Micr. Soc., p. 7, pl. i, figs. 10*a*, *b*, 11.

Remarks.—The species has been recorded from the Gault of Northern France and Folkestone by Berthelin and Chapman. According to Chapman the *C. cultrata* of the Red Chalk of Speeton belongs to this species.

Horizon.—Present in B base *c* and D_6 mid. One specimen in each bed.

Cristellaria sternalis, Berthelin. (Pl. XIX, Fig. 3.)

Cristellaria sternalis, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 54, pl. iii, figs. 2*a*, *b*.
C. sternalis, Chapman, 1896: Journ. Roy. Micr. Soc., p. 8, pl. ii, figs. 1*a*, *b*.

Remarks.—The only specimen found has a smaller keel than the one figured by Chapman. The species is known from the Gault of Northern France and Folkestone.

Horizon.—Present in B base *c*. One specimen.

Cristellaria orbiculata (Roemer). (Pl. XIX, Fig. 6.)

Planularia orbiculata, Roemer, 1842: Neues Jahrbuch, p. 278, pl. vii B, fig. 6.

Remarks.—Described by Roemer from the Hils Clay of Escherhausen, which Reuss (Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 8, 1862) thinks is probably the Speeton Clay of his classification; it does not seem to have been found since.

Horizon.—Found in B base *c*. One specimen.

Cristellaria rotulata (Lamarck). (Pl. XVIII, Fig. 25.)

Lenticulites rotulata, Lamarck, 1804: Annales de Muséum, vol. v, p. 188, No. 3; Tableau Encycl. et Méth., pl. cccclxvi, fig. 5.
Cristellaria münsteri, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 77, pl. ix, figs. 3*a*, *b*, 4*a*, *b*.
C. rotulata, Brady, 1881: Chall. Rep., vol. ix, p. 547, pl. lxix, figs. 13*a*, *b*.

Remarks.—This is by far the commonest species of *Cristellaria* in the Speeton Clay of Yorkshire, and, with the exception of *Pulvinulina caracolla*, is much the commonest of all the Foraminifera in that formation. A few specimens are doubtfully referred to *C. rotulata*, var. *macrodiscus*, Reuss (Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 78, pl. ix, figs. 5*a*, *b*, 1862).

C. rotulata is known from the Middle and Upper Hils and the Speeton Clay of North Germany (Reuss), from the Red Chalk of Speeton, the Gault of Folkestone and Northern France, and many other Cretaceous deposits, and probably ranges back as far as the Ordovician System (Ulrich, Journ. Cincin. Soc. Nat. Hist., vol. v, p. 119, pl. v, figs. 2, 2*a*, 1882 (?)). It is still common in many parts of the world, and is found at all depths (Brady).

Horizon.—Present in B base *b*, B base *c*, C_1, C_2, C_3, C_9, D_3, D_6. Abundant.

Sub-family POLYMORPHINÆ.

Polymorphina, d'Orbigny.

Polymorphina fusiformis, Roemer. (Pl. XIX, Fig. 12.)

Polymorphina (*Globulina*) *fusiformis*, Roemer, 1838: Neues Jahrb. für Min., p. 386, pl. iii, fig. 37.
P. (*G.*) *angusta*, Egger, 1857: Neues Jahrb. für Min., p. 290, pl. xiii, figs. 13–15.
P. lanceolata, Reuss, 1851: Zeitschr. d. deutsch. geol. Gesell., vol. iii, p. 83, pl. vi, fig. 50.
Globulina prisca, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 79, pl. ix, fig. 8.
Polymorphina fusiformis, Brady, Parker, & Jones, 1870: Trans. Linn. Soc., vol. xxvii, p. 219, pl. xxxix, figs. 5*a*–*c*, and woodcut *e*, p. 220.

Remarks.—Brady has subdivided this species again into *P. angusta*, Egger, and *P. lanceolata*, Reuss (Chall. Rep., vol. ix, p. 563, 1884), but Chapman reunites them (Journ. Roy. Micr. Soc., 1896, p. 11, pl. ii, fig. 9). A number of specimens have been found, and they show transitional stages between the types recognized by Brady. The form is recorded by Reuss from the Upper Hils and the *Minimus*-clay of Germany, by Berthelin (Mém. Soc. géol. France, sér. III, vol. i, p. 57, pl. iv, figs. 20*a*, *b*, 1880) from the French Gault, and by Chapman from the Gault of Folkestone. Burrows, Sherborn, & Bailey record it as *P. lactea* in the Red Chalk (Journ. Roy. Micr. Soc., 1890, p. 561), and it is still living. Brady states that it ranges down to 2,400 fathoms.

Horizon.—Fairly abundant in Upper C_2; a single specimen in B base *c*.

Polymorphina problema, d'Orbigny. (Pl. XIX, Fig. 13.)

Polymorphina (*Guttulina*) *problema*, d'Orbigny, 1826: Ann. Sci. Nat., vol. vii, p. 266, No. 14; Modèle No. 61.
P. (*G.*) *communis*, d'Orbigny, loc. cit., p. 266, pl. xii, figs. 1–4; Modèle No. 62.
P. problema, Brady, 1884: Chall. Rep., vol. ix, p. 568, pl. lxxii, figs. 19, 20; pl. lxxiii, fig. 1.

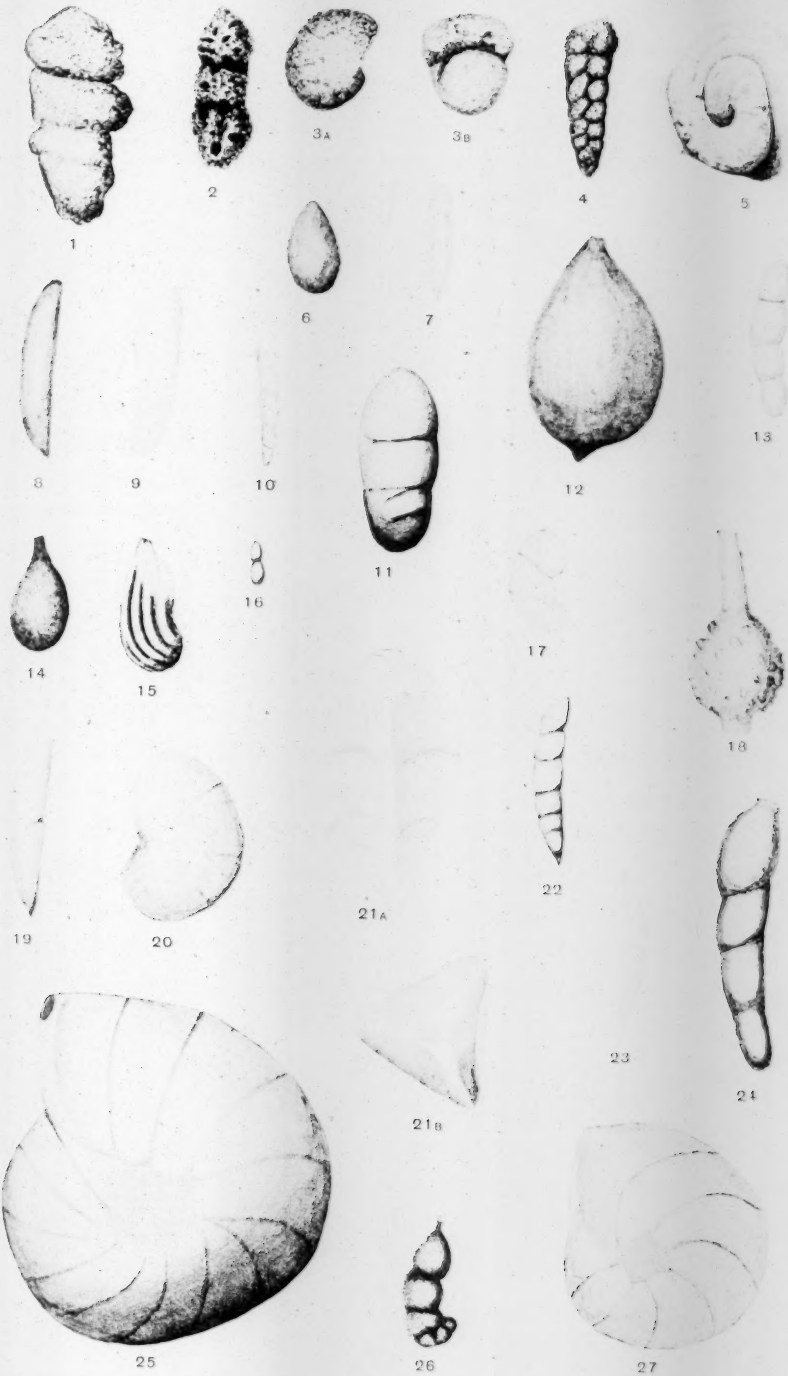
Remarks.—The species is recorded by Chapman (*P. communis*) from the Gault of Folkestone (Journ. Roy. Micr. Soc., 1896, p. 13, pl. ii, fig. 15) and the Lower Cretaceous of Surrey (Q.J.G.S., vol. l, p. 716, 1894); by Berthelin from the Gault of France, as *P. cretacea* (Mém. Soc. géol. France, sér. III, vol. i, p. 58, 1880), and from the Red Chalk of Speeton, as *P. gibba*, by Burrows, Sherborn, and Bailey (Journ. Roy. Micr. Soc., 1890, p. 561), and it is still living. The greatest depth from which it was recorded by the *Challenger* Expedition was 155 fathoms.

Horizon.—Present in Upper C_2. One specimen.

EXPLANATION OF PLATE XVIII.

All figures are magnified 50 diameters except Fig. 25.

FIG. 1. *Reophax scorpiurus*, Montfort.
,, 2. *Bigenerina nodosaria*, d'Orb.
,, 3. *Haplophragmium latidorsatum* (Bornemann). 3*a*, lateral aspect; 3*b*, oral aspect.
,, 4. *Gaudryina filiformis*, Berthelin.
,, 5. *Ammodiscus gordialis* (Jones & Parker).
,, 6. *Lagena globosa* (Montagu).
,, 7. *Nodosaria* (*Dentalina*) *fontannesi*, Berthelin.
,, 8. *Lagena apiculata*, Reuss, var. *danfordi*, var. nov.
,, 9. *Nodosaria* (*Dentalina*) *roemeri*, Neugeboren.
,, 10. *Marginulina linearis*, Reuss.
,, 11. *Nodosaria* (*Glandulina*) *lævigata*, d'Orb., var. *strobilus*, Reuss.
,, 12. *Lagena apiculata*, Reuss.
,, 13. *Nodosaria* (*Dentalina*) *lorneiana*, d'Orb.
,, 14. *Lagena lævis* (Montagu).
,, 15. *Marginulina jonesi*, Reuss.
,, 16. *Nodosaria calomorpha*, Reuss.
,, 17. *Marginulina glabra*, d'Orb.
,, 18. *Nodosaria hispida*, d'Orb. Broken specimen.
,, 19. *N.* (*Dentalina*) *siliqua* (?), Reuss. Broken specimen.



E. L. Sherlock, Del. ad nat. Bemrose & Sons Ltd., Collo.

Foraminifera, Speeton Clay, Yorkshire.

FIG. 20. *Cristellaria cephalotes*, Reuss.
,, 21. *Rhabdogonium insigne*, Reuss. 21*a*, lateral aspect; 21*b*, oral aspect.
,, 22. *Nodosaria* (*Dentalina*) *legumen*, Reuss.
,, 23. *Marginulina debilis*, Berthelin.
,, 24. *Nodosaria* (*Dentalina*) *communis*, d'Orb.
,, 25. *Cristellaria rotulata* (Lamarck). Magnified 33⅓ diameters.
,, 26. *C. gracillissima*, Reuss.
,, 27. *C. gaultina*, Berthelin.

(*To be concluded in the next Number.*)

III.—Some new Rock-building Organisms from the Lower Carboniferous Beds of Westmorland.

By Professor E. J. Garwood, M.A., F.R.S., F.G.S.

(PLATES XX AND XXI.)

IN my account of the Lower Carboniferous rocks of the North-West of England, published in 1912, I figured an organism, probably the thallus of a calcareous alga, which plays an important part as a rock-builder at the base of the *Seminula gregaria* sub-zone in Westmorland and Lancashire.[1] More recently, at the meeting of the British Association in Birmingham,[2] I pointed out the need of some distinctive name for this important form, and suggested for it the generic name of 'Ortonella', from the village of Orton, near Tebay, in the neighbourhood of which this fossil is specially abundant. Two other structures were mentioned at the same time which occur constantly in microscopic sections of the Lower Carboniferous rocks of the North-West of England and elsewhere. The first of these was alluded to under the general descriptive term 'festoon structure', and the other was referred to Gürich's somewhat obscure genus *Spongiostroma*. In view of the zonal value of these organisms in the North-Western Province and the probability that they will be found to be widely distributed in the Lower Carboniferous rocks elsewhere, I propose here to give a somewhat fuller description of these forms than could be attempted in the limits of a presidential address.

Ortonella, gen. nov. (Pl. XX, Figs. 1–4.)

Mode of Occurrence.—The remains of this organism occur in the form of sub-spheroidal nodules varying in size from that of a marble to that of a tangerine orange, the largest example met with having a diameter of 5 cm. (Fig. 1). The fractured surfaces of the nodules show a porcellanous texture and a uniform rich brown tint, while a distinct concentric arrangement is usually noticeable. In transparent slices a fibrous structure radiating from the centre can also be observed with a strong hand lens. The smaller examples resemble, in general appearance, the nodules of *Solenopora* which occur in the underlying sub-zone in Westmorland and likewise the nodules of *Mitcheldeania* which are found so abundantly in the Lower Carboniferous deposits of Mitcheldean and North Cumberland.

Under the Microscope.—The thallus is seen to consist of a series of fine ramifying tubes which radiate from the centre of the nodule in

[1] Q.J.G.S., vol. lxviii, p. 449, pl. xlvii, fig. 2, November, 1912.
[2] Rep. Brit. Assoc. 1913, Section C; also Geol. Mag., Dec. V, Vol. X, pp. 440, 490, 545, 1913.

every direction. The tubes vary slightly in size, the lumina having on an average a diameter of about 32 μ, and individual tubes show a nearly uniform diameter throughout. The tubes are typically straight or so slightly undulating that in thin slices passing approximately through the centre of the nodule many of these tubes remain in the plane of the section for considerable portions of their length (Fig. 2).

The tubes are circular in cross-section, completely separated, and often widely spaced. They show marked dichotomous branching (Figs. 3, 4), the angle of divergence of the branches being usually about 40°, and there appears to be a tendency for this branching to take place in several neighbouring tubes at about the same distance from the centre of the nodule. The tubes appear to be completely devoid of transverse partitions, and no trace of perforations has been observed in their walls. They are now filled partly with crystalline calcite and partly with fine dark marly sediment, while the spaces between the tubes are occupied by similar materials. The concentric appearance of the nodules seems to be due partly to the increased proximity of the tubes where bifurcation occurs and partly to the denser character of the matrix, which has remained more completely entangled where the tubes are in closer approximation.

Genotype.—*Ortonella furcata*, sp. nov. (Pl. XX, Figs. 1–4.) All the examples so far met with in Westmorland belong apparently to one species, which, on account of its marked dichotomous branching, we may appropriately speak of as *Ortonella furcata*.

Horizon.—In the algal layer at the base of the *Seminula gregaria* sub-zone, *Athyris glabristria* zone; Lower Carboniferous, Westmorland and Lancashire.

Localities.—Orton; Ravenstonedale; Shap; Eskrigg Wood, near Summerlands—in Westmorland; and near Low Meathop in Lancashire also, sparingly, at about the same horizon immediately below the Fell Sandstone in North Cumberland and North-West Northumberland. I have also met with a few examples, referable to this species but with somewhat finer tubes, in the *Modiola* beds of Dr. Vaughan's classification near the base of the Lower Carboniferous rocks in the Avon Gorge.

Resemblances and Differences.—In general appearance under the microscope, this organism most closely resembles the genus *Mitcheldeania* described by Mr. Wethered from the Lower Limestone Shales of the Forest of Dean,[1] a fuller account of which was subsequently given by the late Professor Nicholson in 1888,[2] from the Lower Carboniferous rocks of Kershope Foot on the Scottish Border.

Our genus resembles *Mitcheldeania gregaria*, Nich., in the radiating mode of arrangement of its tubes and in the fact that it exhibits dichotomous branching. It differs from it, however, in the smaller size of the tubes, their straight and more uniform character, and their much wider spacing. Again, though both genera exhibit dichotomous branching this takes place much more frequently and

[1] GEOL. MAG., Dec. III, Vol. III, p. 535, Pl. XIV, Fig. 6, 1886, and Proc. Cotteswold Nat. Club, vol. ix, p. 77, 1886.

[2] GEOL. MAG., Dec. III, Vol. V, pp. 16–19, Figs. 1, 2, 1888.

Fig. 1. ½.

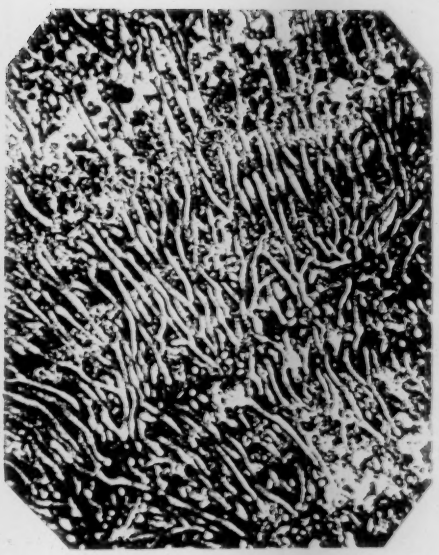


Fig. 2. × 20.

Fig. 3. × 55.

Fig. 4. × 55.

E. J. Garwood, photo. *Bemrose & Sons, Ltd., Collo.*

Ortonella furcata.

uniformly in *Ortonella* than in *Mitcheldeania*, while the angle of divergence of the branches is also much greater in *Ortonella*, thus giving rise to the marked difference in the spacing of the tubes in the two genera. It also differs from *Mitcheldeania*, as described by Nicholson, in the absence of cross partitions to the tubes and the imperforate character of the walls, and also in the general absence of the finer series of tubes which Wethered and Nicholson regard as an essential character of *Mitcheldeania* (Pl. XXI, Fig. 2). The structures described by Nicholson as cross partitions in the tubes are, however, very irregular and frequently entirely absent in the Cumberland examples of *M. gregaria*, while the perforations in the cell-walls mentioned by the same author are very obscure, and, as I have already stated,[1] I have been unable to discover any true pores in the Cumberland specimens of *M. gregaria*, even in those which I have collected from Nicholson's type locality at Kershope Foot. It is possible, therefore, that the large pores figured by Nicholson are in reality the elbows of the undulating tubes intersected by the plane of the section.

As regards the finer series of tubes in *Mitcheldeania* (Pl. XXI, Fig. 2), these appear to be typically present in examples of *M. Nicholsoni* and in most of the larger specimens of *M. gregaria*. I have, however, frequently found them to be absent from small examples of *M. gregaria*, the nodules in this case being entirely made up of the coarser tubes. At the same time it is not an uncommon occurrence to find small nodules entirely composed of the finer tubes without any traces of the coarser forms, and it is open to question whether the two sets of tubes necessarily belong to the same organism. This doubt seems to be strengthened by the occurrence, though rarely, of specimens of *Ortonella* in Westmorland with tufts of fine tubules associated with them, which are indistinguishable from the finer tubes in *M. gregaria*.

Other organisms to which *Ortonella* bears some resemblance are *Girvanella*, Nich., and *Sphærocodium*, Rothpl. It differs, however, from these genera in the radial arrangement of its tubes, which in *Girvanella* and *Sphærocodium* lie in concentric layers round the nucleus. Again, though Rothpletz has described dichotomous branching in *Girvanella*, this is certainly obscure in most British examples, including Nicholson's genotype from Girvan. It appears, however, from Dr. Rothpletz's description, to occur in *Sphærocodium Bornemanni*.

Systematic Position.—The genus *Ortonella*, as shown above, seems to be most nearly allied to *Mitcheldeania* and *Sphærocodium*, and, as both these forms appear referable to the calcareous algæ, *Ortonella* may also be provisionally placed among the Thallophyta. As regards its more definite systematic position, it seems to be most nearly related to the Siphoneæ, but, as Professor Seward cautiously remarks regarding *Girvanella*, *Siphonema*, and *Sphærocodium*, "It is wiser to regard such tubular structures as closely allied organisms, which are

[1] Rep. Brit. Assoc., Section C, 1913, and GEOL. MAG., Dec. V, Vol. X, pp. 440, 490, 545.

probably algæ, but too imperfectly known to be referred to any particular family."[1]

APHRALYSIA,[2] gen. nov. (Pl. XXI, Figs. 3, 4.)

The macroscopic characters of this organism can only be generally inferred, as specimens have not been isolated from the matrix. In translucent sections of the rock, however, these organisms are seen to occur as thick incrustations surrounding fragments of various organisms and, if isolated, they would appear as small nodules up to 10 mm. in diameter, having a slightly lobulate surface, thus resembling nodules of *Girvanella* or *Solenopora*.

Under the microscope the nodules are seen to be built up of a series of semicircular and semi-elliptical plates arranged in irregular alternating rows, having the convex surfaces of the plates directed uniformly outwards away from the centre of growth, giving a general appearance of wreaths of bubbles, encrusting fragments of shells, or the thalli of *Ortonella* and other algal forms. The growth usually starts with small plates resembling hollow blisters attached by their edges to the surface of the object which serves as a nucleus. The size of the blister-like cells increases in the succeeding row, and usually averages ·12 mm. in height in the centre. The length of the cells varies according to the position of the sections, but the height of the arch is remarkably uniform in the majority of cases, whatever the length of individual cell. These curved plates, bounding the outer surfaces of the cells, sometimes occur as very thin dark lines, but they are more frequently represented by a pale orange-coloured film or stain. This colouring matter may extend inwards so as to occupy a quarter or even a third of the cavity, the thickness depending apparently on the angle made by the wall with the plane of the section. There is a complete absence of circular sections, so that the cells cannot be tubular in character. The structure is thus shown to consist of a series of alternating rows of elongated, highly arched plates, each plate resting with its edges supported by the plates of the row below, exactly like a tangle of soap bubbles or a mass of foam.

No other definite structures can be made out, but occasionally in sections cut tangentially to the surfaces of the nodules a few curved plates may be observed (exactly similar in structure and colour to the boundary walls) which appear to divide up some of the more elongate cells. These may, however, be the edges of other cells cut by the plane of the section. This organism is frequently intergrown with layers of a flocculent deposit which may be classed under the general term '*Spongiostroma*'.

The exact nature of *Aphralysia* is somewhat doubtful. Its mode of growth and its intimate association with *Ortonella* and '*Spongiostroma*' would appear to suggest algal affinities, but the comparatively large size of its cells and their mode of growth differentiate it from any examples of fossil calcareous algæ known from the Lower Palæozoic rocks.

[1] Seward, *Fossil Plants*, vol. i, p. 160, 1898.

[2] 'Chain of foam.' From ἄφρος, 'foam,' and ἅλυσις, 'a chain.'

Fig. 1. Spongiostroma. × 25.

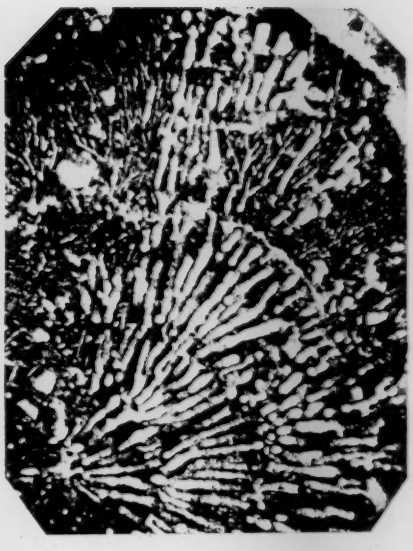


Fig. 2. Mitchelldeania. × 26.

Fig. 3. Aphralysia. × 13.

Fig. 4. Aphralysia. × 30.

E. J. Garwood, photo. *Benrose & Sons Ltd., Colls.*

Though the material so far to hand does not afford sufficient evidence to warrant our assigning to it a definite systematic position, there can be no doubt as to its importance as a rock-forming organism.

Genotype.—*Aphralysia carbonaria*, sp. nov. (Pl. XXI, Figs. 3, 4.) The specimens so far met with appear to belong to only one species, for which on account of its widespread occurrence in the Lower Carboniferous rocks we suggest the specific name of '*carbonaria*'.

Horizons and Localities.—It occurs abundantly in the Lower Carboniferous rocks of the North-West of England at the base of the *Seminula gregaria* sub-zone. In the Shap and Ravenstonedale districts of Westmorland; also at the same horizon at Low Meathop in the Arnside district; more sparingly in the *Solenopora* sub-zone in Stone Gill, Ravenstonedale; in the upper *Dibunophyllum* sub-zone (*Girvanella* Nodular Band) at Humphrey Head in the Grange district; in association with *Mitcheldeania gregaria* in the Whitehead Limestone at Mitcheldean; at about the same horizon again in North Cumberland and near Tosson in Northumberland; also in the *Modiola* beds underlying the Bryozoa bed in the Avon Gorge, Clifton, exposed in the lower railway cutting near Cook's Folly.

'Spongiostroma.' (Pl. XXI, Fig. 1.)

In 1906 Gürich described and figured a number of somewhat obscure structures from the Dinantian rocks of the Namur district (under the generic names *Spongiostroma*, *Malacostroma*, etc.) which he regarded as encrusting Foraminifera.[1] More recently Professor Rothpletz has described two species of *Spongiostroma* (*S. balticum* and *S. Holmi*) from the Silurian rocks of Gotland.[2] Gürich's reference of these structures to the Protozoa appears to be decidedly speculative, while the features which he selects for the subdivision of the different forms into genera and species are very indefinite, and the detailed structure often varies greatly, even in the same specimen.

In the Lower Carboniferous rocks of Westmorland we meet with many similar structures which in places contribute largely to the formation of the deposit. They occur especially in the 'Algal Layer' at the base of the *Seminula gregaria* sub-zone, associated with *Ortonella* and *Aphralysia* (Pl. XXI, Figs. 3, 4), and occasionally form undulating layers several inches in thickness. I have observed similar structures in the rocks of North Cumberland and West Northumberland and the Border country, also in the Forest of Dean, the Avon Gorge, and South Wales,[3] and it is probable that they will be found to be widely spread in shallow-water deposits of Dinantian age in Europe.

In transparent slices under low magnification they frequently show a general appearance of stratification lying roughly parallel to the bedding-planes (Pl. XXI, Fig. 1), while fine layers of a similar deposit are often seen under higher powers to be intergrown

[1] *Mém. du Mus. Roy. d'Hist. Nat. de Belgique*, t. iii.
[2] *Kungl. Svenska Vetenskap. Hand.*, Bd. xliii, No. 5, 1908.
[3] In specimens sent me by Mr. C. H. Cunnington.

concentrically with specimens of *Ortonella* and *Aphralysia* (Pl. XXI, Figs. 3, 4). Under the microscope no definite cell-structure can be made out, and the general appearance is that of an indefinite flocculent precipitate of carbonate of lime which has the appearance of having been thrown down from solution as the result of the abstraction of CO_2 from water containing calcium bicarbonate in solution. The character of these structures, coupled with the general absence of definite mechanical and organic fragments, where they occur, points strongly to their organic origin, while their constant association with *Ortonella*, *Mitcheldeania*, and *Solenopora* would suggest that the conditions under which they were formed were of a lagoon character suitable for the growth of marine algæ. At the same time the absence of definite cell-structure suggests that they represent the insoluble $CaCO_3$ precipitated in an amorphous condition as the result of absorption of CO_2 from the water by growing plants rather than definite structures built up in the cells of calcareous algæ.[1] General precipitation of this kind is well known to botanists at the present day. Thus the famous 'Sprudelstein' of Carlsbad has often been stated to have originated in this manner, though this has been disputed by some recent observers. There cannot, however, be any doubt regarding the action of certain plants in this connexion.

During the progress of the bathymetrical survey of the Scottish lochs, abundant precipitation of calcium carbonate, due to plant action, was observed. In addition to lime-encrusted Characeæ in the lochs of Lismore, lime-encrustations were observed on the stones of the shore formed by minute lithophilous algæ, in the process of their metabolism, while certain plants such as *Myriophyllum spicatum* and *Potamogeton* were found to produce heavy precipitates of $CaCO_3$. The former plant is stated by Mr. George West[2] to be so heavily coated with encrustations of carbonate of lime that the plants are often unable to rise to the surface for the purpose of pollenization. Were it not for the fact that the majority of the Scottish lochs lie in areas where the rocks are practically devoid of lime, this phenomenon would doubtless have been met with more frequently.

In the Swiss lakes also (Geneva, Neuchâtel, etc.) the blue-green algæ, according to Chodat, cause important precipitation of $CaCO_3$. Indeed, in recent years there has been a growing conviction among writers on lake deposits (C. A. Davis,[3] Wesenburg-Lund,[4] Weltner,[5] Passarge,[6] and others) that the lime deposits in lakes are chiefly, if not entirely, due to organisms, among which plants often play a very important part. It seems highly probable, then, that similar amorphous deposits are also taking place in shallow seas, especially where lagoon conditions prevail and algæ flourish. Our knowledge of such

[1] Thus, if water is saturated with calcium bicarbonate, then for each gram of CO_2 abstracted by plants, 2·3 grams of $CaCO_3$ are precipitated.

[2] *Bathymetrical Survey of the Fresh-water Lochs of Scotland*, vol. i, p. 213, 1910.

[3] *Journal of Geology*, Chicago, vol. viii, p. 485; vol. ix, p. 491.

[4] *Meddel fra Dansk Geolog. Foren. Kobenhavn*, vii, 1.

[5] *Archiv f. Naturges.*, vol. lxxi, p. 277.

[6] *Jahrb. d. Königl. Preuss. Geol. Landesanst*, vol. xxii, p. 79.

deposits appears at present to be very scanty, and further investigation is greatly needed.

EXPLANATION OF PLATES XX AND XXI.

PLATE XX.

FIG. 1. *Ortonella furcata*, gen. et sp. nov. Section through a typical nodule. Natural size. Base of the *Seminula gregaria* sub-zone, Ravenstonedale, Westmorland.
,, 2. *O. furcata*. Thin section through above. × 20.
,, 3, 4. *O. furcata*, showing dichotomous branching of tubes. × 55.

PLATE XXI.

FIG. 1. *Spongiostroma* cf. *Malacostroma concentricum*, Gürich. × 2·5. Base of the *Seminula gregaria* sub-zone, Fawcett Mill, near Orton, Westmorland.
,, 2. *Mitcheldeania gregaria*, Nich. × 26. Showing coarse and fine tubes. Zone of C_1–C_2 of Dr. Vaughan's classification. Scully Grove, Mitcheldean.
,, 3. *Aphralysia carbonaria*, gen. et sp. nov. × 13. Intergrown with layers of a flocculent deposit—'*Spongiostroma*.'
,, 4. *A. carbonaria*, gen. et sp. nov. × 30. From the 'Algal Band' associated with *Ortonella*. Base of *Seminula gregaria* sub-zone, Wath, near Orton, Westmorland.

IV.—GYPSUM AND ANHYDRITE IN GENETIC RELATIONSHIP.

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IN certain geological horizons where there is evidence of continuous deposition of salts from the waters of inland basins, gypsum and anhydrite are found closely associated, while in other similar horizons gypsum may occur with apparently no trace of anhydrite. Some Upper Silurian occurrences in North America, the Lower Carboniferous of Eastern Canada, and the Zechstein of Northern Germany are illustrative of the association of both minerals, while in more recent gypsum horizons anhydrite seems to appear less frequently. Even in the one horizon anhydrite is found to be of only local occurrence. In New York and in Michigan the Salina formation contains both gypsum and salt deposits, but practically no anhydrite. In Manitoba, on the other hand, in an Upper Silurian formation which cannot be definitely correlated with the Salina of New York, but which is at any rate of approximately the same age, gypsum and anhydrite occur in the most intimate relationship.

The conditions of stability of gypsum and of anhydrite, whether in presence of water or of salt solutions, were investigated by van't Hoff and his co-workers by vapour-tension methods. The relationship of both forms to the half-hydrate ($CaSO_4 . \frac{1}{2}H_2O$), which is obtained by ordinary calcination processes, and to 'soluble anhydrite', which is formed when precipitated gypsum is maintained at temperatures

60°–90° C. *in vacuo* in contact with phosphorus pentoxide, was also studied. The results may be briefly tabulated as follows[1]:—

Natural anhydrite transforms into gypsum—
(*a*) At 30° C. in presence of a saturated solution of sodium chloride.
(*b*) At 66° C. in presence of water.

Soluble anhydrite transforms into gypsum—
(*a*) At 65° C. in presence of a saturated solution of sodium chloride.
(*b*) At 89° C. in presence of water.

Half-hydrate transforms into gypsum—
(*a*) At 11° C. in presence of a saturated solution of magnesium chloride.
(*b*) At 76° C. in presence of a saturated solution of sodium chloride.
(*c*) At 101·5° C. under atmospheric pressure.
(*d*) At 107° C. in presence of water.

If, then, at a certain stage of evaporation an inland sea is saturated as regards calcium sulphate and sodium chloride, and if the temperature is not below 30° C., anhydrite will form. The frequent association of anhydrite and salt beds in nature would consequently seem to indicate, at the time of deposition, rather high temperatures in the bodies of water from which these minerals were precipitated. This view has usually been taken in connexion with the Stassfurt Beds, and was suggested by van't Hoff as a geological deduction from his experimental work. If, however, gypsum beds, intercalated with beds of salt, be in course of time buried to depths of 1,500 feet or more, and if the average surface temperature be taken as 15° C., the gypsum is, under such conditions, above transformation temperature, and will presumably go gradually over into anhydrite. Arrhenius and Lachmann[2] believe that in the case of the Stassfurt sulphates the faunal evidence is against the probability of temperatures so high as 30° C. in the inland seas of Northern Germany in late Permian times, and that the anhydrite of Stassfurt is a transformation product from originally deposited gypsum. The reverse reaction would necessarily take place, and gypsum would again be formed, in the case of the anhydrite horizon reaching a higher relative level owing to the denudation of the overlying beds, or in the case of the abstraction of the associated salt beds by solution.

In the course of an investigation, for the Geological Survey of Canada, of the gypsum and the salt horizons in the limestones of Palæozoic age in Manitoba, the writer has had occasion to examine a surface exposure of gypsum, with associated anhydrite, at Gypsumville, the present terminus of the Canadian Northern Railway branch line which skirts the east side of Lake Manitoba. The following section was obtained from the face of the quarry that is now being operated:—

(*e*)	Surface capping (gypsite and soil) .	1–3 feet.
(*d*)	Red argillaceous gypsum . . .	29 ,,
(*c*)	White foliated gypsum . . .	75 ,,
(*b*)	Bluish-grey anhydrite	25 ,,
(*a*)	Hard reddish gypseous rock . .	5 ,,

[1] *Untersuchungen über die Bildungsverhältnisse der ozeanischen Salzablagerungen*, 1912, p. 189.
[2] *Geologische Rundschau*, Bd. iii, Hft. iii, p. 141.

The immediately underlying beds are not exposed in this locality, but from the evidence of a core section they appear to be a reddish calcareous clay. The anhydrite forms heavy beds 2–4 feet thick, which show no evidence of disturbance. The overlying white gypsum beds are 2–4 inches thick, and are sharply folded. At the quarry there is a dip, which is only of local significance, towards the north; consequently the anhydrite appears only at the south end of the quarry. The line of contact between the gypsum and anhydrite follows fairly closely the bedding-plane, wherever the top of the anhydrite beds is exposed. A similar close association of the two minerals may be observed in several of the gypsum exposures which occur in the Gypsumville district, and which cover in the aggregate an area of nearly 5½ square miles. In one locality, 6 miles north-east of the quarry, anhydrite occurs at the surface, and is found by boring to extend at least 90 feet vertically downwards, entirely free from gypsum; while half a mile further east an exposure of gypsum of considerable extent appears, with only occasional outcrops of anhydrite.

The horizon in which these surface exposures lie is near the top of the Upper Silurian. The highest beds of the Silurian in Manitoba, as determined by Kindle,[1] skirt the western side of the gypsum outcrop, and consist of thin-bedded magnesian limestones, rather poor in fossils, but characterized by the presence of *Leperditia hisingeri*. These beds overlie the gypsum. Underlying the gypsum horizon are dolomites and dolomitic limestones, in which but few fossils have been found. They belong to the Stonewall Series, which is probably the western equivalent of the Niagara and Guelph horizons in the east. The Palæozoic beds, which form in this locality a western fringe to the Canadian Shield, dip almost imperceptibly towards the south-west. The topography is relatively flat, the elevations of the surfaces of Silurian and Devonian formations ranging from 750 to 900 feet above sea-level. An escarpment of soft Cretaceous shales rises rather sharply from the Upper Devonian Limestones on the west side of Lake Winnipegosis and Lake Manitoba to a height of 2,500 feet above sea-level. The distance from the Gypsumville quarry (elevation 850 feet) to the top of the escarpment, measured in an east and west line, is approximately 80 miles. Almost certainly these Cretaceous shales formerly extended eastwards over the gypsum exposures, which were consequently buried to a depth of 1,700 feet at least. While salt has not been found in association with the gypsum horizon, the presence of glauberite ($CaSO_4 . Na_2SO_4$) from a core obtained by drilling at the quarry shows that the concentration of sodium ions was high in the solution from which the calcium sulphate was precipitated; and on the west side of Lake Winnipegosis numerous salt springs occur in the Upper Devonian, so that the gypsum horizon, when deeply buried, was probably saturated with a brine solution. Conditions may then have been favourable for the transformation of gypsum into anhydrite when the Upper Silurian was buried beneath the Cretaceous shales. The problem in this case

[1] Geological Survey of Canada, Summary Report, 1912.

and in similar cases is whether the anhydrite was originally deposited, or was formed by transformation at a later stage, when, owing to increasing depth of sedimentation, a temperature of 30° C. was undoubtedly reached.

In seeking to explain the origin of deposits such as these, one may consider the two alternatives that are generally offered: First, the theory of Ochsenius,[1] that the salts have been deposited from an arm of the sea, which is in only partial communication with the outer ocean; second, the theory that limestones have been converted into the sulphates by the action of water containing SO_4 ions. In the case under consideration the gypsum does not grade laterally into limestone: basal red beds occur, and one complex sulphate at least has been found. Such facts are not in accord with the theory that the beds were originally limestones. On the other hand, the sequence gypsum, anhydrite, and gypsum (with glauberite) is explicable on the assumption of an evaporating basin, separated from the outer ocean by a bar over which calcium salts might reach the inner evaporating pan. The more soluble chlorides of sodium and potassium, sulphates of magnesium and complex salts, have not been found in this locality; but brines which reach the surface in Upper Devonian limestones contain a high percentage of potash, and may be genetically connected with this horizon.

The applicability of Ochsenius' hypothesis to the Stassfurt salts has recently been questioned by Walther,[2] who believes that the salts were precipitated from an inland basin entirely cut off from the sea, that, as the shallower parts of the lake dried up, the salts were redissolved and carried down to the deep basins, and that only such deep basins are represented by the present distribution of the deposits. Grabau[3] has made a still wider application of the desert hypothesis in his explanation of the Salina deposits of New York and Michigan. He considers that the land surface of the Niagara Limestones, reworked by weathering agents under desert conditions, supplied—mainly through the connate waters with which the limestones were impregnated—the salts which were finally carried down, by streams due to intermittent rains, into circumscribed desert basins. The annual rings at Stassfurt might be accounted for, according to Walther, as due to salts carried down after successive rainfalls; and the same authority considers that the absence of fossils cannot be explained if communication with the open sea remained established during the whole period of precipitation. In the Gypsumville deposits there are no annual rings; no indication of subaerial weathering has been found in the underlying rock; the homogeneous character of the heavy anhydrite beds is difficult of explanation on a desert erosion hypothesis; and the absence of fossils in the anhydrite-gypsum section might be accounted for, as at Stassfurt,[4] by postulating a rather extended bar where communication was made with the outer ocean,

[1] *Die Bildung der Steinsalzlager und ihrer Mutterlangensalze*, 1877.
[2] *Lehrbuch der Geologie von Deutschland*, 1910.
[3] Mining and Metallurgical Society of America, Bulletin 57, p. 39; also *Principles of Stratigraphy*, 1913, ch. ix.
[4] Arrhenius & Lachmann, l.c., p. 142.

so that the organisms which entered these inimical waters might be able to effect their escape. In the district in question such a barrier would, in all probability, lie far towards the north. In the limestones of Devonian age the fauna is distinctly European in type, and seems not to have commingled with that of the New York and Michigan Devonian seas till late Devonian times. These Devonian limestones in the Mackenzie River basin overlap the Silurian beds on the edge of the Archæan shield, and the character of the underlying Silurian in that district has not been ascertained. At a single exposure, however, on the Bear River, gypsum is found interstratified with dolomites.[1]

To return to the main problem before us, the primary or the secondary character of anhydrite. It is very evident that transformations take place with extreme slowness. In the district to which particular attention has been devoted in this paper, the Cretaceous shales were elevated, and in all probability eroded, in early Tertiary times. Since that time anhydrite has been the unstable modification. Notwithstanding this, solid anhydrite may be found, as already indicated, to a depth of over 90 feet, with no gypsum on top. It is true that glacial erosion has taken place since that time, but boulders of compact anhydrite which lie on the surface fully exposed to atmospheric influence are surrounded by only a thin film of gypsum. Geological evidence points unmistakably to a very prolonged lag in the transformation anhydrite → gypsum, and it is not at all likely that at temperatures not much above 30° C. the change gypsum → anhydrite goes on more rapidly. Indeed, the burying of gypsum under considerable thicknesses of subsequently formed sediment tends to maintain the gypsum as such, for there is an increase of volume in the transformation gypsum → anhydrite + water, and although the liquid phase will at once seek regions of lower pressure, it is the volume relationships at the moment of transformation that regulates transformation conditions.

In the opinion of the writer, the anhydrite in the Upper Silurian of Manitoba is primary, and the order gypsum–anhydrite–gypsum represents the mineralogical sequence of deposition in Upper Silurian times. The presence of gypsum underneath the anhydrite is rather conclusive evidence against the secondary character of the anhydrite zone. With regard to the upper gypsum, there has unquestionably been a certain amount of transformation into gypsum of the top beds of the anhydrite since Tertiary times. Analyses of the upper anhydrite beds show a continuously increasing water value from the middle of each bed to the margin, an evidence that a gradual change is taking place. Besides, the folded structure of the gypsum beds is most naturally explained as a 'Gekröse'[2] phenomenon, due to an internal increase of volume in the solid phase, consequent on transformation. It is believed, however, that only the lowest beds of the upper gypsum have so originated, and that the internal pressure has been transmitted to the overlying gypsum, which had been precipitated as such at a late stage of the evaporation.

[1] J. M. Bell, Geological Survey of Canada, 1899, xii, 25 C.

[2] Koken, *Zentralb. f. Min.*, u.s.w., 1902, 3.

The physical conditions would seem to have been somewhat as follows:—Owing to elevation in late Niagara times, the sea withdrew towards the north, and an inland arm of the northern sea was placed in imperfect communication with the outer ocean. Chemical precipitation of the carbonates took place, followed by deposition of the sulphates as gypsum. Later, communication with the ocean closed, the temperature of the waters of the basin rose, and anhydrite began to form. At a still later stage lower temperatures prevailed, probably because of the entrance of ocean waters, and continuous deposition of gypsum ensued. The concentration of sodium salts became so great that part of the sodium ions was precipitated in the form of double sulphate. It is still an open question whether evaporation reached the stage of the deposition of the chlorides. When, finally, deeper-water conditions again prevailed, carbonates and traces of sulphates were thrown down, and formed the limestone which now represents the highest beds of the Silurian in Manitoba.

To summarize, the following conclusion of general applicability may perhaps be legitimately derived from the study of a particular gypsum–anhydrite association. While secondary transformations are possible at considerable depths, and also at the surface, the general character of gypsum–anhydrite deposits may be accounted for most directly, and with least difficulty, as due to original deposition. This applies most obviously in cases where the bedding-plane defines with fair accuracy the contact between anhydrite and gypsum. Where anhydrite occurs in masses irregularly distributed through gypsum rock, transformation processes at or near the surface have played a relatively greater part; but direct geological evidence has yet to be adduced before the theory can be accepted that transformation of gypsum to anhydrite, at great depths below the surface, takes place to such an extent as to be of geological importance.

REVIEWS.

I.—Memoirs of the Geological Survey of Scotland. Geology of Central Ross-shire (Explanation of Sheet 82). By B. N. Peach, LL.D., F.R.S., John Horne, LL.D., F.R.S., and others; with Petrological Notes by J. S. Flett, D.Sc., LL.D., F.R.S. 8vo; pp. vi, 114. Edinburgh, (1913) 1914. London: T. Fisher Unwin, 1 Adelphi Terrace, W.C. Memoir, 2*s.* 3*d.*; map, 2*s.* 6*d.*

THE area included in Sheet 82 is approximately 429½ square miles in extent; about 2½ square miles of salt water at the head of Loch Carron enter into the limits of the map. With the exception of a small part of Inverness-shire in the south-east corner, on either side of Glen Strath Farrar, the whole map falls within the County of Ross.

This is a typical Highland area, in which cultivation and population are reduced to a minimum and confined to the seaboard and a few spots along the larger river-valleys. The ground is mountainous, wild, and inaccessible, and is given up to deer forest and grouse moor, with small and decreasing areas of sheep-grazing at Kinlochewe, Loch Carron, and Scardroy.

The mean annual rainfall exceeds 60 inches, while at Loch Torridon and Glen Carron, situated in narrow glens among lofty mountains, the average fall is respectively 88·58 and 90·23 inches, and at the latter station has reached as high as 109 inches for one year.

This tract of country may be described as a more or less denuded high mountain plateau, falling towards the north-east and reaching its greatest elevation along a line drawn from Beinn Eighe, in the north-west corner of the map, to An Riabhachan and Sgùrr na Lapaich on the southern margin. The most obvious features in the surface-relief are the three through-valleys which cross the region in a nearly parallel E.N.E.–W.S.W. direction.

Ten rivers and eight lakes (or lochs) bespeak the abundant rainfall of the district, while Loch Torridon and Loch Carron, the heads of fiords, are obviously the seaward extension of drowned valleys pre-glacial in origin and formed when the land stood at a higher level than at the present time. Subsequent glacial erosion produced over-deepening of the valleys and excavated a succession of rock-basins, now all beneath sea-level, in their floor, but they were in all probability partly eroded below the present sea-level before the glaciation of the country. After the disappearance of the ice from the lower part of the valleys, moraines, fluvio-glacial gravels, raised beaches, and river alluvia were left behind very generally, partially filling up many of the lochs with moraine deposits.

Turning to the solid geology depicted on the map, one is struck by the great antiquity of the rock-groups which form the entire area. Thus "The whole of the ground east of the River Carron and of a line drawn from Achnashellach to Kinlochewe is occupied by crystalline metamorphic rocks—the siliceous and perlitic schists of the Moine Series—surrounding inliers of complex gneisses of Lewisian type. The latter are most widely developed in the eastern part of the area, where the largest inlier is found in the basin of the Meig, and forms a great part of the mountain Sgùrr a' Ghlas Leathaid. Other smaller masses occur in Glen Orrin, in Glen Strath Farrar, and round the head of Loch Monar. These inliers are all east of the 'Moine thrust'.

"Another large mass of Lewisian Gneiss enters the map on either side of Loch Carron, and is continued as a narrow and interrupted belt along the west side of Strath Carron, and northwards through the Coulin Forest to within a short distance of Kinlochewe. This western belt forms part of the thrust masses situated west of the Moine thrust; the portion south of Loch Carron lies to the east of that line of movement. A portion of a small inlier of unmoved Lewisian rocks appears on the western margin of the map 2½ miles north of the head of Loch Torridon.

"The remaining north-western portion of the sheet is occupied by sedimentary rocks of Cambrian and Torridonian age, these two formations alternating in parallel belts along lines of thrust or natural outcrop; while, in the unmoved area, the Cambrian quartzites cap the highest peaks of Laithach and Beinn Eighe" (p. 10).

Sixty-four pages (chapters iii to viii) are occupied with a detailed account of the Moine thrust and its effect upon the tectonics of the

area in relation to the Lewisian Gneiss, the Torridonian Sandstones and Cambrian strata. The description is aided by a series of sections: (1) from Laithach by Sgùrr Dubh to the River Coulin (p. 20); (2) from Beinn Damh across Chinn Deirg to Coulags, Strath Carron (p. 23); (3) from Strath a' Bhathaich by Glas Bheinn to Kirkton on Loch Carron (p. 24); (4) diagrammatic sections, showing the relations of the Moine Series to the Lewisian Gneiss south of Attadale, Loch Carron. The areas west and east of the Moine thrust and the inliers of Lewisian Gneiss and their petrography are described. Then follows a detailed account of the Moine Series between Glen Carron and Glen Docherty; the Monar area, the valley of the Meig, Glen Orrin, Glen Strath Farrar; and Glen Cannich. The elucidation of these very disturbed and complex districts is greatly assisted by a small map (fig. 5, p. 59) of the Beinn Dronaig area and a diagrammatic section (fig. 6, p. 70) across the northern region from Kinlochewe to the River Meig, showing the massive siliceous granulites, the flaggy siliceous schists, the pelitic gneiss and lower siliceous schists of the Moine Series, and the Applecross and Diabaig Groups and Lewisian Gneiss of the Torridonian Series which are affected by them. Fossils are hardly to be expected in such highly altered, squeezed, and contorted strata, but Fucoid Beds are recognized by Dr. Horne and "*Salterella* (Serpulite) Grits are traceable through parts of the Coulin and Achnashellach Forests, where they are reduplicated in places by folding and reversed faults. Of special importance is the occurrence in the Fucoid Beds of a band of pisolitic ironstone, from 18 inches to 2 feet thick, in the Allt nan Dearcag, one of the sources of the Coulin River, about 2 miles north from Achnashellach station. There can be no doubt that it represents the layer of pisolitic ironstone in the same subgroup on the northern slopes of Meall a' Ghiubhais which yielded to Mr. Macconochie remains of Trilobites and Echinoderms. The band at Allt nan Dearcag contains *Hyolithes*, and under the microscope plates of *Eocystites* and fragments of the tests of Trilobites have been observed" (p. 18).

In the Bibliographical Appendix of works relating to the geology of the district a paper has accidentally been omitted. It is: 1880, Hicks, Henry, and Davies, T., "Pre-Cambrian Rocks of West and Central Ross-shire," Geol. Mag., 1880, pp. 103, 155, 222, 266, and 329.

Eight excellent collotype plates illustrate the most important points in the scenery of Ross-shire and ten text-figures.

II.—The Geology of the Country near Fareham and Havant. By H. J. Osborne White, F.G.S. pp. 96. 1913. Price 1*s.* 9*d.*; map 1*s.* 6*d.*

THIS Memoir is an explanation of Sheet 316 of the Geological Maps on the scale of 1 inch to the mile, surveyed on the 6 in. scale by Messrs. W. Whitaker, C. Reid, and C. E. Hawkins. The district dealt with is situated for the most part in the south-east of Hampshire, the remainder in South-Western Sussex. There are only four small towns in the area, Fareham, Havant, and Emsworth in the south and Bishop's Waltham in the north-west.

The western end of the South Downs runs through the northern part of the district. To the north of this ridge the Gault and Lower Greensand come on in the Wealden area near Petersfield. To the south the ground slopes gently to the wooded track of the Forest of Bere on Eocene strata. Southward again from this tract comes the Chalk ridge of Portsdown, which declines eastward and westward from a point above 400 feet near Southwick.

The lowest strata exposed in the district are the Sandgate Beds, which occur near the north-eastern corner and are believed to be about 70 feet thick. The succeeding Folkestone Beds here consist of yellow and white sands, with seams of carstone near the middle; they are not known to be fossiliferous, their thickness is locally about 150 feet. The Selbornian, comprising the Gault and Upper Greensand, is grouped under zonal headings, and most of the local Gault clays are considered to belong to the zone of *Hoplites interruptus*. The Greensand immediately below the Chalk is not well exposed; it was not seen eastward of Barrow Hill within the present district, but it may be continuous with the similar deposit observed south of Petworth.

Four chapters are devoted to a consideration of the Chalk. This formation occupies rather more than half the country, and probably attains a thickness of 1,200 feet in the southern part of the district, where it is most fully developed. The junction of the Upper and Middle Chalk is somewhat difficult to trace in the field, as there is no hard band of Chalk Rock at this horizon as in other districts. The line on the map has been drawn at the base of the markedly flint-bearing beds or rather below the actual top of the Middle Chalk. The generally accepted zones of the English Chalk have been recognized, and due note is taken of the recent work of Messrs. Griffith and Brydone.

With regard to the Lower Chalk, this is confined to the northern part of the area. Its lowest member, the so-called Chloritic Marl, is about 3 feet thick; this is followed by bluish marls belonging to the zone of *Schloenbachia varians*; the succeeding zone of *Holaster subglobosus* is composed of yellowish-white chalk. The top of the Lower Chalk is plainly marked by the *Actinocamax plenus* Marls. The thickness of the Lower Chalk is estimated at 220 feet.

In the Middle Chalk the Melbourn Rock appears to be represented by a bed of firm sub-nodular white chalk, 2 to 4 feet thick at the base of the *Cuvieri* zone, which here consists of alternations of lumpy white chalk and of thinner roughly laminated marly chalk. The zone is about 70 feet thick. The *Terebratulina lata* zone consists mainly of white chalk with some thin seams of grey marl, and contains a good number of small flints. It is about 120 to 130 feet thick. The total thickness of Middle Chalk is about 200 feet.

The Upper Chalk in the southern part of the district is probably about 750 feet thick. It here comprises six zones, from *Holaster planus* to *Belemnitella mucronata* inclusive. The greater part of the last-named zone is, however, missing, owing to erosion in early Eocene times. The zone of *Holaster planus* is composed of distinctly nodular chalk; flints are common, small, and with thick rinds. The sub-zone

of *Heteroceras reussianum* has not been recognized, and the Chalk Rock often developed at that horizon is wanting. Little is seen of the zone of *Micraster cor-testudinarium*. Mr. Brydone's estimate of the combined thickness of the *Cor-testudinarium* and *planus* zones at Warnford is 112 feet. The zone of *Micraster cor-anguinum* is 226 feet thick at Warnford, and consists mainly of soft white chalk with abundant flints. There are few exposures, as is also the case in the *Marsupites testudinarius* zone. The chalk of this zone is very soft and contains few flints. The *Uintacrinus* and *Marsupites* bands are both recognizable, and each is probably about 35 to 40 feet thick. The zones of *Actinocamax quadratus* and *Belemnitella mucronata* are well exposed. The former is about 300 feet thick; in its lower part it is soft white chalk very similar to that of the underlying zone; it becomes gradually more marly and contains an increasing number of flints towards the top; all the exposures of consequence are in Portsdown. Details are given of the subdivisions of this zone advocated by Messrs. Griffith and Brydone. The zone of *Belemnitella mucronata* is well developed near Fareham, where there appears to be a thickness of about 60 to 70 feet.

The Memoir deals in detail with the various exposures of the several zones, and an extensive zonal list of fossils is given. The junction of the Cretaceous with the Eocene beds is nowhere clearly shown, but their unconformability is proved by the relations of their outcrops in different parts of the district. The *mucronata* beds of Portsdown have nowhere been observed along the northern boundary of the Eocene strata between Upham and Funtington. This discordance is part of a widespread unconformity which takes the form of an overstep of the Cretaceous by the Eocene in a northward direction; thus more than half the Upper Chalk is cut out in the distance of 50 miles between the Isle of Wight and the Berkshire Downs.

The Eocene beds immediately overlying the Chalk belong to the Reading Series; the seams of glauconitic sand which are common in other areas are found to be wanting, as also are the commonly associated oyster-shells and fish-teeth. The bulk of the formation consists of clays and loams. The average thickness is estimated at about 110 feet. Notes are given of exposures in both the northern and southern outcrop.

The thickness of the London Clay is given at about 250 feet. It is made up of evenly stratified silty clays, loams, and loamy sand, with thin beds or seams of impure shelly limestone and of flint pebbles.

Details of sections are given and a list of fossils from the Catisfield cutting and from Fareham Station. Short chapters deal with the Bagshot Sands and Bracklesham Beds; the thickness of both varies considerably. A chapter on Tectonic Structure and Land Forms is of considerable interest. It is considered that during the Eocene and Oligocene periods the eastern part of the Hampshire Basin never rose much above sea-level, the main folds being developed in Miocene times, and the various folds and faults are discussed in detail. A few interesting points in connexion with the drainage of the country are also brought forward. A number of unstratified superficial deposits are grouped under the heading of Clay-with-Flints;

they are considered to be a product of the disintegration of the Tertiary beds and the Chalk, and are assigned to the subaërial class. Their relation to the solid formation is discussed.

The remaining superficial deposits—raised beach, gravels, and brickearth—have apparently all been laid down in water. Two small patches of raised beach are mentioned, which rest a little below 100 feet O.D. Plateau gravels rest in patches on the Eocene beds at altitudes between 30 and 315 feet; they are considered to be mainly old river-deposits, and the various types are dealt with in detail. The Valley Gravels are often chalky, when they are known as Combe Rock; they occur in all the principal valleys, and in this connexion mention is made of the sheet of chalk and flint rubble which clothes the southern slope of Portsdown. The brickearth is a brown loam which thinly cloaks the edges of the Chalk and Eocene on the lower steps of the coastal plain.

In dealing with the Alluvium it is pointed out that by the close of the Pleistocene period the larger rivers were running in valleys cut down, through the gravel and brickearth-covered flats of the coastal plain, to a depth of perhaps 20 or 30 feet below the ordinary high-tide level of the present day, the coastline lying then farther to the south. Subsidence has allowed the sea to advance once more northward, drowning the lower reaches of the valleys, and filling them with alluvial deposits. The mud and associated deposits are said to attain a thickness of 35 feet at the Docks in Portsmouth Harbour (south of the district).

A chapter on economic aspects of the geology, including notes on the water-supply, concludes the memoir.

III.—Tertiary Echinoids of the Carrizo Creek Region in the Colorado Desert. By William S. W. Kew. University of California Publications: Geology, Vol. VIII, No. 5, pp. 39–60, pls. i–v. Berkeley, April 16, 1914.

THE Echinoid fauna of North America is known through a seriously disjointed record. The marvellous profusion of Palæozoic forms cannot be matched in any other country, but Mesozoic types are practically negligible. It is not until the later Tertiary stages are reached that the history of Echinoid evolution is resumed, and then in a few coastal regions only. Much of our knowledge of the fauna of these relics of Tertiary subsidence is due to work carried out under the auspices of the University of California. Hence it is that the regions bordering on the Gulf of California have given almost the only evidence of American Cainozoic Echinoids. In view of the extreme wealth of existing Echinoderm life in the shore waters of the area, the study of the corresponding forms of a time not long past has a peculiar interest.

The age of the Carrizo formation, the horizon of the Echinoids described in the paper under review, has not been precisely determined. It has been correlated with the Etchegoin Series (of Upper Miocene or Lower Pliocene age), but, as the writer indicates, the Echinoid fauna is so nearly akin to the existing one of the

neighbourhood that an even later date is possible. In this connexion it is interesting to note that the affinities of the known fauna of the Carrizo formation are definitely with that of the Gulf of California, and have no apparent relation to that of the Pacific region—an indication that the Peninsular Mountains then, as now, formed a continuous barrier between the two districts.

The Carrizo Series is divided into two sections, from the lower of which all the Echinoids have been exclusively collected. The upper part of the series seems to have been formed under brackish conditions, during the gradual silting-up of the Gulf. The lower series exhibits two facies—a littoral zone of reddish conglomerate and arkose, and an outer zone, reaching as much as 50 fathoms in depth, represented by finer sediments. It is interesting to find that the species of Echinoids that predominate in one type of deposit are rare or absent in the other, although representatives of the same genera are abundant in both.

One species of *Hipponoë*, three of *Clypeaster*, one of *Encope*, and an indeterminable specimen of *Cidaris* are described. All but one of the species are new, but the impression left by a perusal of the text and a study of the plates is that their chief claim to novelty lies in their fossil condition. There seems to be something akin to the point of view of a century ago in the specific separation of recent and fossil types in spite of their resemblances. In every case but one the species described are admitted to differ from the existing forms of the district in mere details of size and proportion. That they are ancestral to the species of the present day seems clear, but it seems doubtful whether, in the majority of cases, their ancestral characters render them sufficiently distinct for more than varietal separation.

Perhaps the most interesting of the forms described is *Encope tenuis*, which is practically identical with the recent *E. californica*, but has the radial lunules of the latter species represented by the primitive condition of marginal notches. *Clypeaster carrizoensis*, the species whose living representative is unknown, appears from the figure to be more nearly related to *Laganum* than to *Clypeaster*.

It is greatly to be hoped that further researches may be made into the fauna of the Carrizo formation, and that thereby the history of the peculiar and teeming fauna of the Gulf of California may be more fully written. In the meantime this paper should be of value as showing the possibilities underlying such research in the solution of problems of both biological and geographical interest.

H. L. H.

IV.—Geology of the Strata traversed by the D'Urban Artesian Well Boring, 1913. By Professor J. B. Harrison, M.A., C.M.G. pp. 18. British Guiana Combined Court, Annual Session, 1914.

PREVIOUS well-borings in British Guiana appear to have tapped water derived from beds of sand at less than 200 feet below the surface. These sands were thought to be stratified beds, but they are now shown to be more or less lenticular masses of wind-blown sand:

the water derived from them was either ferruginous or saline, and the supply was not continuous.

The present boring passed through 178 feet of alluvial deposits, resting on a considerable thickness of dune sand, which yields highly ferruginous water. Below 280 feet the beds are estuarine and marine in character, and these continue until granitic rocks, presumed to be Archæan, are reached at 579 feet. These formations supply evidence of a depression of the granitic rocks to a depth of not less than 280 feet. The dune sands mark an elevation or cessation of movement, and indicate a long period of rest followed by a further depression, during which the upper alluvial deposits were formed.

Water was found at nine levels, but the only good drinking-water was yielded by two beds of sand immediately above the granitic rocks. This water is derived from the thick lateritic and lithomargic deposits which rest on a floor of igneous rocks in the high lands of the colony. The water from the lowest level contains only 5·3 grains of solid in solution per gallon and has a temperature of 90·4° F. The mean daily flow from August 25 to November 27 was 198,000 gallons. Analyses are given of the water obtained from nine different levels in the boring.

REPORTS AND PROCEEDINGS.

Geological Society of London.

1. *April* 8, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Evolution of the Essex River System, and its Relation to that of the Midlands." By John Walter Gregory, D.Sc., F.R.S., F.G.S., Professor of Geology in the University of Glasgow.

The post-Eocene geology of Essex must be learnt from its gravels and their non-local constituents. In the absence of any rock which affords a certain proof of its route, the effort was made to determine the direction of transport by tracing the variations in the proportions and size of the non-local constituents. This test shows that the quartzites and felsites came from the north-west and the Lower Greensand cherts from the south and south-east.

A. The gravels may be classified as follows:—

(1) The oldest series. The Brentwood group, which consists of redeposited Bagshot Beds and of local materials only.

(2) The Danbury Gravel, which was deposited before the arrival of the felsites, and at the beginning of the arrival of the Lower Greensand cherts.

(3) The Braintree Gravel, which is largely composed of quartzitic drift, with abundant Lower Greensand cherts and some felsites that were probably derived from the Lower Greensand conglomerates north-west of Essex.

(4) and (5) Glacial and post-Glacial gravels.

B. Judged from the distribution and dates of appearance of the non-local constituents in these gravels, the evolution of the Essex river systems appears to have been as follows:—

(1) The Thames-Kennet River was formed along the axis of the syncline of the Thames Basin. The Thames, therefore, began its existence in the Upper Eocene and Oligocene periods, and then flowed north-eastwards and passed out of Essex to the north of Clacton. Tributaries down the northern slope of this syncline introduced the quartzite-drift from the Midlands, while flints from the Chalk were washed down both slopes.

(2) As denudation lowered the upraised borders of the Thames Basin, the Lower Greensand was exposed in the North Downs, and chert from it was carried into Essex. The chert began to reach Mid-Essex after the deposition of the Brentwood Gravels (probably Upper Eocene) and during the deposition of the higher-level Danbury Gravels (360 feet). As the Upper Greensand had been exposed in the Weald during the Lower Eocene period, it is most probable that the Lower Greensand would have been exposed during the Oligocene period. Its exposure in the Miocene period is indicated by the occurrence of its cherts in the crags, combined with the existence of a plain in Northern Kent before the oldest Pliocene (Diestian). As the oldest Danbury Gravels give no evidence of redeposition they are, at the latest, Miocene.

(3) Further denudation exposed the Lower Greensand conglomerates of Cambridgeshire, and felsites from them were carried into Mid-Essex, where they arrived later than the highest-level Danbury Gravel, but during the deposition of the Braintree Gravel on an old plain, at about 200 feet above the present sea-level. The Braintree Gravels were not later than the end of the Miocene period, although many of them have probably been redeposited in the Pliocene.

(4) The Upper Miocene, or at least pre-Diestian, earth-movements lowered the Weald, and led to the deposition of the Diestian Sands on the worn-down northern edge of the Wealden anticline. This subsidence deflected the Thames southwards to its present line. Its former route was closed by the uplift of Mid-Essex by the reversed fault or fold along the Mid-Essex Range. The latest date for this movement is indefinite. It has been suggested that the great height of the Danbury Gravels is due to uplift. The most definite evidence as to the age of the earth-movement shows that it was later than the existence of the Blackwater and Chelmer Rivers. These rivers, after the diversion of the Thames to its present line, must have extended their old valleys south-eastwards; the Blackwater and the Colne excavated the estuary of the Blackwater, and the Chelmer, following a parallel route, discharged through the Crouch. These rivers and most of the larger Essex river valleys were pre-Glacial, but the smaller valleys in Northern, Central, and Western Essex were completely filled during Glacial times, and so the streams, such as the Upper Roding, have had to excavate post-Glacial valleys.

(5) A post-Glacial change led to the deepening of the Chelmer Valley between Chelmsford and Maldon, whereby the Chelmer was

diverted to the Blackwater and the Crouch left as a beheaded estuary or föhrde.

(6) The Lower Thames and Essex river systems are therefore due to the Eocene earth-movements which formed the London Basin, and the coeval uplift of the English Midlands started thence a radial drainage. The streams to the south-east cut the wind-gaps on the Chiltern Hills, and the drainage to the south-west flowed along a subsidence on the north-western side of the Jurassic escarpment as the Warwickshire Avon and the Lower Severn.

2. "The Topaz-bearing Rocks of Gunong Bakau (Federated Malay States)." By John Brooke Scrivenor, M.A., F.G.S.

Gunong Bakau is a peak, 4,426 feet high, in the main range of the Malay Peninsula. It is composed of porphyritic granite, into which have been intruded veins of quartz-topaz rock, and, at a later date, masses and veins of topaz-aplite.

The quartz-topaz rock has quartz and topaz as constant constituents. Other important constituents, which, however, are not always found, are cassiterite, zinnwaldite rich in iron and showing the axial figure of a uniaxial mineral, and tourmaline. The zinnwaldite is only known to occur in quantity in one vein: elsewhere it is sometimes found forming patches in the quartz-topaz rock.

The topaz-aplite contains a small amount of cassiterite.

Where the quartz-topaz veins cut the granite a 'reaction border' of schorl-rock, and, in one case, of greisen, is found. These reaction borders differ widely from the veins themselves.

Evidence is given in detail, showing that the quartz-topaz vein-rock is not an alteration product of a pre-existing rock, but was intruded as a quartz-topaz magma.

Ore-bodies formed by pneumatolytic alteration of granitic rocks were once worked on Gunong Bakau, and they differed markedly from the quartz-topaz rock.

It is believed that the difference between the familiar pneumatolytic products, schorl-rock, and greisen, on the one hand, and the quartz-topaz rock on the other, is that, in the former case, rocks that had consolidated on the edge of a granite-mass were altered by media coming from deeper parts of the mass; whereas, in the latter, an accumulation of similar media attacked part of the still molten magma deep down in the igneous mass, and the heat generated by the reactions that took place caused the portion of the magma attacked to boil up and consolidate in the granite as an intrusive vein-rock. Segregation of the first-formed minerals during cooling led to the irregular distribution of the constituent minerals in the veins.

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2. *April* 29, 1914.—Dr. A. Smith Woodward, F.R.S., President, and afterwards, William Hill, Vice-President, in the Chair.

The following communications were read:—

1. "On the Lower Jaw of an Anthropoid Ape (*Dryopithecus*) from the Upper Miocene of Lérida (Spain)." By Arthur Smith Woodward, LL.D., F.R.S., Pres.G.S.

The author describes and discusses the greater part of a mandibular ramus and symphysis of *Dryopithecus fontani*, lent to him by Professor L. M. Vidal, of Barcelona. The specimen was found by Señor José Colominas in association with the *Hipparion* fauna at Seo de Urgel, in the Province of Lérida (Northern Spain). It is, therefore, the latest jaw of an Anthropoid ape hitherto discovered in Europe, although probably contemporaneous with the isolated Anthropoid teeth from the Bohnerz of Würtemburg and the well-known Anthropoid femur from the Sands of Eppelsheim (Hesse-Darmstadt). The relatively small size of the first molar is to be regarded as a primitive character, lost in all modern Anthropoids except some Gibbons. The shape of the mandibular symphysis is almost remarkably primitive, with the surface of insertion for the digastric muscle nearly as large as that of the ancestral Macaques (for instance, *Mesopithecus*). The anterior face of the symphysis slopes directly upwards from the front edge of this insertion, as in the Macaques, some Gibbons, and very young individuals of the Chimpanzee, Gorilla, and Orang. It thus differs considerably from the mandibular symphysis in adult individuals of these existing Apes, in which the lower portion of the slope curves backwards into a more or less well-defined flange or shelf of bone, while the digastric insertion is reduced in extent. The mandibular symphysis of *Dryopithecus* is, indeed, intermediate in shape between that of the Upper Miocene or Lower Pliocene *Mesopithecus* and the Lower Pleistocene *Homo heidelbergensis*. So far as its lower jaw is concerned, *Dryopithecus* is, therefore, a generalized form from which modern Anthropoid apes and man may have diverged in two different directions.

2. "The Structure of the Carlisle-Solway Basin, and the Sequence of its Permian and Triassic Rocks." By John Walter Gregory, D.Sc., F.R.S., F.G.S., Professor of Geology in the University of Glasgow.

The Carlisle-Solway basin has been generally represented as a syncline, with the Solway resting on a great thickness of Triassic rocks. A boring made near Gretna in 1794 shows, on the contrary, that Lower Carboniferous rocks crop out there at the surface. This boring shows that the basin is not a simple syncline.

The evidence derived from the boring necessitates reconsideration of the Permo-Triassic sequence in North Cumberland, as to which the Geological Survey maps and memoirs are not in agreement. According to Mr. Holmes's view, expressed in the memoir, there are two series of gypseous shales, one above and the other below the St. Bees Sandstone. According to the classification adopted on the maps, there is only one horizon of gypseous shales, which is below the St. Bees Sandstone. Mr. Holmes's case rests on the identification of the rock at the bottom of the Abbeytown boring as St. Bees Sandstone. If that rock be accepted as the Penrith Sandstone, it is unnecessary to assume two series of gypseous shales. Arguments are given to show that the evidence for the existence of the St. Bees Sandstone at the bottom of the Abbeytown and Bowness borings is quite inconclusive, and the fact is improbable. The view adopted by the Geological Survey map as the alternative

to Mr. Holmes's conclusion, that the area west and north-west of Carlisle consists of Keuper deposits, is also improbable, the rocks thus identified being the gypseous shales above the Penrith Sandstone.

CORRESPONDENCE.

THE CARLISLE-SOLWAY BASIN.

Sir,—In the discussion on the Carlisle-Solway basin at the Geological Society (Abstr. Proc., No. 958) I omitted to reply to Mr. Lamplugh's argument that the Point of Ayre bore in the Isle of Man supports the identification of the rock at the bottom of the Abbeytown bore as the St. Bees Sandstone. The correlation on which this view is based does not seem to me supported by the evidence. The Point of Ayre bore has been recorded in detail by Mr. Lamplugh (Isle of Man memoir, 1903, pp. 585–6), and he there classed the beds above the St. Bees Sandstone as the "Saliferous Marls" and obviously regarded them as Keuper (ibid., p. 291). Mr. Lamplugh's argument depends upon the correlation of these beds with the Gypseous Shales at Abbeytown. As no specimens of the rocks from these bores are available, we can only compare them by the bore records. The following table summarizes the records:—

	Abbeytown. Times mentioned.	Point of Ayre. Times mentioned.
Beds—		
Shale	61	0
Micaceous Shale	1	0
Sandy Shale	10	0
Marl	0	36
Sandy Marl	0	3
Marlstone	0	19
Sandstones	6	4
Breccia	0	1
Minerals—		
Salt in beds	0	18
Salt in shale	1	0
Salt in marl and marlstone	0	27
Gypsum	36	18
Colours—		
Red	54	0
Brown	0	42
Green	17	0
Blue	20	11
Purple	1	0
Grey	8	22
White	8	0
Thickness	79 beds, average 10′ 5″	80 beds, average 6′ 2″

The two series agree in being argillaceous members of the red rock series, but the differences between the two sets of rocks seem far greater than the resemblances. They both contain some gypsum and salt. But the only salt recorded in the Abbeytown journal is present in a 5 ft. layer of red shale with gypsum and salt. In the Point of Ayre bore the salt occurred in eighteen beds, which yielded 76 ft. 8 in. of cores of salt, in addition to numerous salt-bearing marls.